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SENIOR DIVISION ADVANCED-LEVEL CHEMISTRY

Educators' Report

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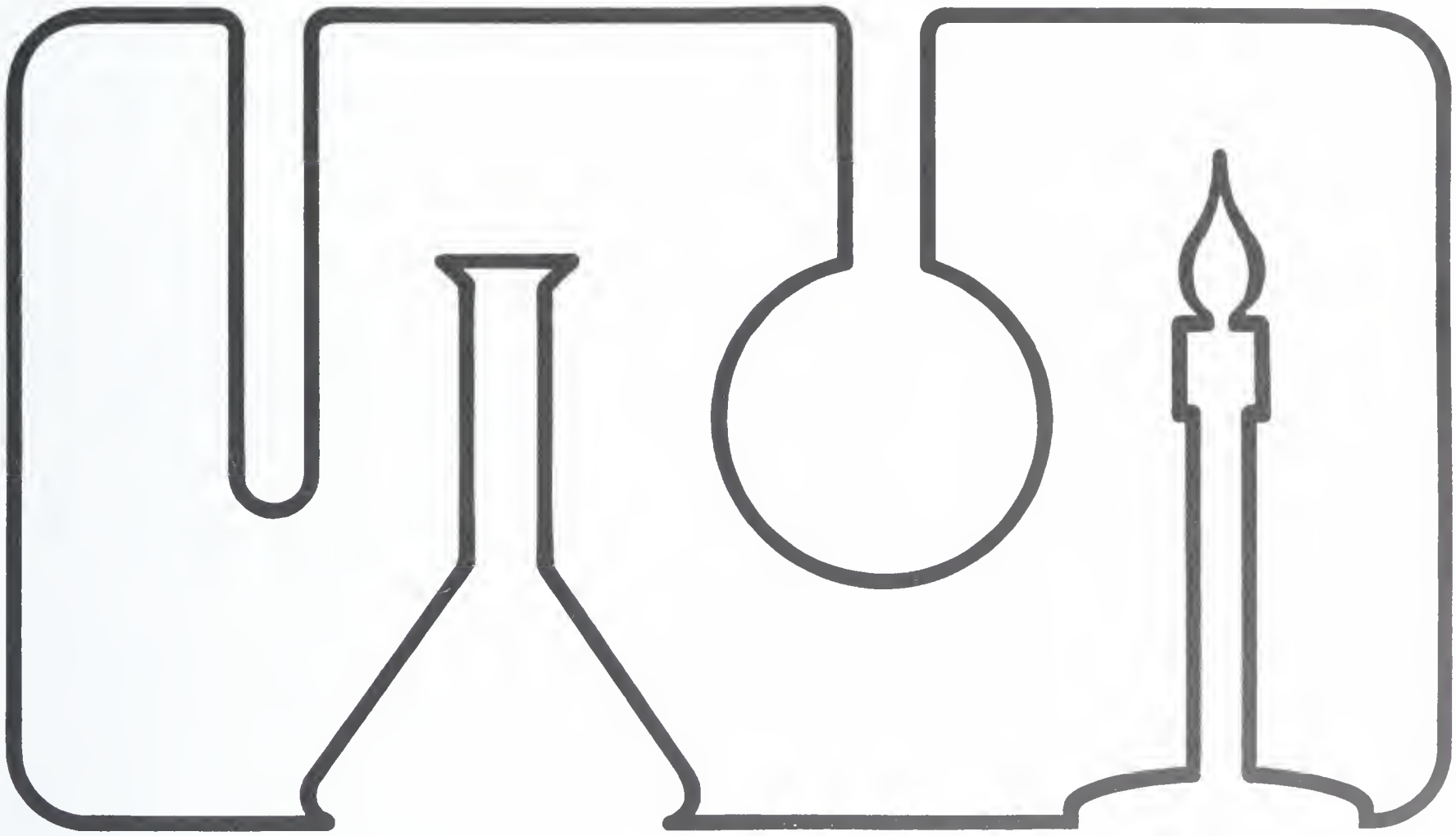

PROVINCIAL REVIEWS

CHEMISTRY AND PHYSICS

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SENIOR DIVISION ADVANCED LEVEL CHEMISTRY

EDUCATORS' REPORT

1. CURRICULUM MANAGEMENT IN ONTARIO

In recent years, several developments have led to a need for the reviewing and clarifying of curriculum policies, processes and responsibilities at both the provincial and local level. These developments include:

- a demand by the public for increased responsiveness and accountability on the part of educators;
- economic and technological changes as they affect school programs;
- an emerging consensus in the educational community on the cyclic nature of review, development and implementation functions;
- many publications focussing on implementation and evaluation;
- indications, from research and reviews, that school boards have experienced widely varying degrees of success in addressing curriculum review, development and implementation.[1]

The Ministry of Education in Ontario has adopted the cyclic process of Curriculum Review Development and Implementation (CRDI) as a major concept in the management of curriculum. The Resource Guide *Curriculum Management* (1988) provides a useful summary of the concept and its application to education in Ontario.

An integral part of the CRDI cycle is the Review component, which can be defined as "the systematic gathering, analysis, interpretation and evaluation of information concerning educational programs". Reviews can provide information that will both provide initiatives and direction for program improvement as well as deliver information that can be used for public accountability.

As a part of the CRDI process at the Provincial level, the Ministry of Education has embarked upon a program of Provincial Reviews. These reviews form a part of the Ministry of Education's ongoing commitment to the monitoring of programs in all subject areas and help to inform the public about the performance of the Ontario educational system. Reviews are conducted by the Ministry of Education for the following purposes:

- To provide a curriculum-based process of public accountability for the province and for local boards of education.

- To determine the level of student achievement and program effectiveness at the provincial level as a basis for public reporting and decision making.
- To identify strategies that will enable local program improvement and ensure the effective implementation of Ministry guidelines.
- To establish baseline information on both student achievement and program effectiveness for comparison with future reviews.
- To provide instruments, procedures and baseline information for use by schools and boards in local reviews.

This Report to Educators is designed to present, in detail, the results of the **Provincial Review of Senior Division Advanced Level Chemistry**, which was conducted in the spring of 1988. A summary document, *Senior Division, Advanced Level Chemistry - A Report Card for Ontario*, has also been prepared.

2. SCIENCE IN ONTARIO SCHOOLS - A CURRICULUM IN TRANSITION

A great deal of attention has been paid recently to science education at both the national and provincial levels. A number of studies and reports have led to the initiation of the first major reform of science education in 20 years.

2.1 Research in Science Education

An important initiator of this reform was the Science Council of Canada Study in 1984[2]. The report, *Science for Every Student: Educating Canadians for Tomorrow's World*, indicated that

science is not taught in a way that reflects the nature of science nor is it taught in a way that has any relevance to students in terms of societal implications or applications. At approximately the same time (in 1985), a research study, the *Second International Science Study* (SISS)[3] was carried out under the auspices of the International Association for the Evaluation of Educational Achievement (IEA). While the Science Council report was designed to influence policy and stimulate discussion on science education, the SISS study was intended to provide a database which might be used by policy makers. Ontario's results in the SISS study are reported in the *Ontario Science Report Card(1987)* [4].

A complimentary study carried out by the Science Teachers' Association of Ontario (STAO) produced a position paper on science curriculum. This position paper *A Rationale for Quality Science Education in the Schools of Ontario* [5] presented 46 recommendations for curriculum development in science in Ontario.

2.2 Ministry of Education Initiatives

The Ontario Ministry of Education has undertaken a number of initiatives to renew the science curriculum. Three of these are:

Ontario Assessment Instrument Pools for Chemistry and Physics (1982):-a large pool of assessment instruments in a number of subject areas. OAIP pools for senior division chemistry and physics were released in 1982, and extensive field trials of these were conducted in 1983.[6]

Science: Intermediate and Senior Divisions (1987): a new guideline for all science courses in the Intermediate and Senior Divisions. The knowledge component of many of the courses has not changed dramatically from previous guidelines. However, significant changes have

been mandated in the approach to the teaching of science in Ontario. [7]

Science is Happening Here (1988): a policy statement for science in the Primary and Junior Divisions.[8]

It is expected that both current and future Provincial Reviews of various aspects of the science curriculum will provide appropriate "snapshots" of the existing curriculum against which to measure the implementation of these new initiatives.

3. INTRODUCTION TO THE CHEMISTRY REVIEW

The Provincial Review in Senior Division, Advanced Level Chemistry was carried out at two levels:

- At the provincial level, where a representative sample of schools was chosen;
- At the board level, where boards were given the opportunity to conduct a board review involving all schools in which Senior Division Advanced Level Chemistry was taught.

Data collected from schools involved in the provincial review provide the basis for provincial reports, while school boards who chose to be involved, receive board results.

Since the implementation of the new guideline is scheduled to begin in September 1989, units common to both the existing guidelines (**S-17D 1966**), and new guidelines (**Science: Intermediate and Senior 1987, Parts 13 and 14**) were chosen for review.

3.1 Features of the Provincial Review Process

Provincial Reviews in Ontario are a curriculum-based approach to program assessment. The process includes the collection of data on the **Intended, Implemented, and Attained Curriculum.** This model for program reviews has evolved from Ontario's participation in the Second International Mathematics Study (SIMS) during the years 1980-1983.[9]

Information was gathered from students, teachers and school boards in Ontario. More than 12 000 students and their teachers participated in the provincial sample. These participants came from 186 schools offering instruction in English, as well as all 40 schools in which the course was given in French. Individual students and teachers were not identified in the review results.

The review collected the following information:

- courses of study prepared at the school level to indicate learning objectives, teaching strategies, evaluation techniques and resources
- details about teaching strategies used in the chemistry classrooms including resources, methodologies, evaluation techniques and instructional time
- student achievement data indicating knowledge of chemistry, the application of chemistry concepts and the ability to perform tasks involving advanced thinking skills.
- student attitudes toward chemistry and the chemistry course.

In this review, student achievement was measured in six content areas. These areas were common to the guideline issued in 1966 and used in schools in the province and to the newly released guideline, which was being implemented by some schools. These were:

1. **Introduction to Chemistry**:- elements and compounds, mixtures and pure substances, laws of chemical combination.
2. **Atomic Structure and Bonding**:- the history of the development of the atomic model, theories of simple chemical bonds, the periodic table of the elements as a means of predicting chemical properties.
3. **Gases and Mole Problems**:- the behaviour of gases and the particles of which they are composed; the use of the Kinetic Molecular Theory to predict the behaviour of different states of matter; the solution of numerical problems dealing with gas laws and the use of the mole as a unit of measure.
4. **Chemical Reactions Quantitative**:- the use the principles encountered earlier in the course to calculate the quantities of materials involved in chemical reactions.
5. **Chemical Reactions Qualitative**:- the patterns of the properties of elements and compounds are examined as they become involved in chemical reactions.
6. **Solutions**:- the properties of solutions, calculations involving concentrations, and reactions taking place in solution.

In addition to these six specific content areas, students were also asked their opinions about their approach to learning chemistry, science education in general, the use of computers, and the role of science in society.

3.1.1 The Intended Curriculum

The primary source of the intended curriculum in Ontario is the Ministry of Education Guideline. A new guideline for Senior Division Advanced Level Chemistry was released in the fall of 1987, but the implementation of this course is not required to begin until September 1989.

3.1.2 The Implemented Curriculum

The Implemented Curriculum was investigated by asking teachers about their teaching of the objectives found in the provincial guidelines, their instructional practices, methods of evaluation, and resources used. Teachers were also asked to describe their instructional use of microcomputers.

3.1.3 The Attained Curriculum

Information on the Attained Curriculum was obtained by assessing student achievement on a selection of questions. A team of chemistry educators chose 110 selected-response (multiple-choice) questions from the Ontario Assessment Instrument Pool (OAIP) Chemistry, published in 1982. Five extended-response questions were also designed by the team, based on questions found in the OAIP.

Students were asked questions concerning their background and study habits, and their opinions on a on variety of science-related topics.

3.1.4 Review Administration

The data collected was scored and analysed by the Ministry of Education. A study of the student achievement results from the Provincial sample was done by a Provincial Interpretation Panel. This panel, composed of representatives of the science education community, trustees and representatives from the public at large rated student performance on the selected-response and extended-response questions. Further details of this process can be found in the appendices. The results of the process are found in Displays 51 and 52.

School and board results for local reviews have been prepared and distributed. This report represents aggregated data from the schools in the provincial sample only.

3.1.5 Comments on the Review Process from Participants

Following the data collection phase, surveys were conducted in which samples from three groups of participants were asked their opinions regarding the review process.

Responses from a random sample of participants, both teachers and administrators, indicated that the review was generally well received. Teachers were interested in the results and in the ways that they may be applied in the school. The instruments and questionnaires were generally well received and teachers and school contacts were on the whole very pleased with the assistance provided in administering the review.

Confidentiality did not appear to be a major problem for most teachers, and concerns expressed by some respondees will hopefully be alleviated by the manner in which the results of the review are handled both provincially and locally. Concerns expressed about motivation of both students and teachers hopefully will be eased as educators become more familiar with the content and process of reviews. Quality communication between the Ministry and review participants will help to build confidence in the review process.

3.2 Nature and Setting of the Chemistry Review

3.2.1 Senior Division Advanced-Level Chemistry

This course is the first part of the Advanced-Level Chemistry program in Ontario schools, the second and final part being OAC Chemistry. The Senior Division course is usually taken by students during either their third or fourth year of secondary school. Students taking it are often planning post-secondary education. Many students follow this course with the OAC Chemistry course to prepare them for university programs in the sciences.

Traditionally the course has been offered at the Grade 12 level, often following a Grade 11 Physics course. The new guideline suggests that the Senior Division Advanced-Level Chemistry course (SCH 3A), be taken during the third year, followed by the Physics course (SPH 4A). Since both courses are at the Senior Division, students may take them in any sequence.

3.2.2 Program Frameworks and Curriculum Emphases

Although the questions in the student assessment section of the review were directly related to content domains which were common to both the existing guideline and to the new guideline, the teaching strategies used or frameworks within which content is presented can vary widely. In the context of this report, a program framework, can be considered to be the general basis upon which decisions about teaching strategies are made. For example, many teachers may have organized their course based on a particular textbook. Other possibilities for program frameworks include those which emphasize the use of particular teaching strategies which make use of cooperative education, independent study, and more teacher-centred methods.

One organizational framework around which curriculum can be designed is that of **Curriculum Emphases.**[10] The intent of this form of curriculum planning is to make science much more relevant for the student. In the teaching of science, content must be accompanied by a purpose. The content of a course specifies what is to be taught, while the purpose deals with the issue of why the content is to be learned. Curriculum emphasis deals with the purpose. Roberts(1982) describes curriculum emphases as follows:[11]

> A curriculum emphasis in science education is a coherent set of messages to the student about science (rather than within science). Such messages constitute objectives which go beyond learning the facts, principles, laws and theories of the subject matter itself objectives which provide answers to the student question: "Why am I learning this?"

The new guideline mandates that teachers use a number of curriculum emphases upon which to build their program.

These curriculum emphases can be grouped under five general headings:

- Solid Foundations Emphasis
- Nature of Science Emphasis
- Practical Applications Emphasis
- Science Technology and Society Emphasis
- Communication

Traditionally, many science courses have been designed around only one emphasis, Solid Foundations. The introduction of alternative curricular emphases constitutes one factor that should positively affect both student achievement and student retention. Research has shown that student achievement is closely related to such approaches to the teaching process. A recent Ontario example is found in the report on the 1983 OAIP Field Trials in Chemistry. This report cited evidence that student achievement was positively correlated to the discussion of scientific issues and values, while negatively correlated to doing problems in class.

Factors affecting student achievement are many and varied, including such factors as the availability of resources, time spent on topic, teaching strategies, the board implementation plan, and availability of laboratory facilities.

Since this review examined material common to both the 1966 and the 1987 guideline, student assessment questions do not reflect all of the emphases that are being implemented by those teachers using the new guideline. Subsequent reviews will measure the real effectiveness of this curriculum renewal.

3.2.3 Sample Selection

Reviews were conducted in both English and French-language schools. Two kinds of reviews took place: Provincial Reviews and Board Reviews. Among English-language schools, a Provincial Review sample of 187 schools, 312 teachers and 11 169 students provided data representative of the entire English-language population of 580 schools, 970 teachers, and 55 000 students involved in Senior Division Advanced Level Chemistry. The Provincial Sample schools were chosen to reflect the diverse nature of Ontario. For example, schools representing all geographical areas were chosen, as well as urban and rural schools, schools from both public and separate boards, and both large and small schools. The data collected from the schools in the Provincial Review Sample is presented in this report.

All French-language schools participated in the Provincial Review. The results from these 43 schools, 44 teachers, and 1221 students are presented in the French-language *Senior Division Advanced Level Chemistry - Educators' Report*.

Apart from the provincial sample, 39 school boards chose to participate in the Provincial Review process by conducting Board Reviews in Senior Division Advanced Level Chemistry. All of the 251 schools, 376 teachers, and their students in these boards participated. (Some anglophone board review schools were also part of the provincial sample, and boards which had more than one francophone school automatically qualify to receive a report for these schools.) Board results for Chemistry have been prepared and distributed for each school board which undertook a board review as well as for those containing more than one Francophone school. These boards received these results by virtue of every Francophone school being involved in the provincial review.

Additionally, school results are being provided to every school which participated in the review. The results for schools which participated as part of a board review are identical to those being provided to those selected as provincial sample schools. Individual school boards involved in board reviews are expected to analyze and interpret the board data and to report publicly on the results.

3.2.4 Data Collection

Several data collection instruments were used to assess the intended, implemented and attained curriculum.

Information on the intended curriculum was obtained from two sources:

A **Course of Study Analysis** carried out on courses submitted by a provincial sample of 100 schools. These were analysed by a team of Ontario science educators. This team determined whether each of a variety of components were present in these documents.

A **Teacher Data Questionnaire** which collected information on teacher opinions and teacher background. This was completed by all teachers.

Analysis of the **implemented curriculum** was carried out using data obtained from three sources:

A **Teacher Practices Questionnaire** which collected information on the instructional practices of teachers such as resources, methodology, evaluation techniques, and instructional time allotment.

A **Curriculum Management Questionnaire** which collected information on curriculum management at the school level and the impact on the Chemistry program. This was completed by the department head or other person responsible for Senior Division Advanced Level Chemistry.

An **Opportunity-to-Learn (OTL) Questionnaire** which all teachers completed, indicating whether students had been taught the concepts and skills necessary to answer the student assessment questions, as well as teacher predictions of student achievement for each question.

The **attained curriculum** was assessed through student responses to questions designed to measure student knowledge and skills, and attitudes toward Senior Division Advanced-Level Chemistry. 110 selected-response (multiple-choice) questions from the *Ontario Assessment Instrument Pool (OAIP) Chemistry*, published in 1982 and five extended-response questions were involved in this section of the review.

3.2.5 Multiple Matrix Sampling

To collect reliable data about student achievement on a large part of the curriculum, 110 selected-response questions and five extended-response questions were asked of the students. To limit the amount of time needed for the assessment and to provide data on a broader range of elements of the curriculum, multiple matrix sampling was used.

Both selected-response and extended-response questions were distributed among five test booklets. The booklets were rotated through each class and each student completed one booklet. The responses obtained from having one-fifth of the students answer each question are generalized to represent student achievement for all students. For most school boards, and for larger schools, these generalizations are very accurate. The document *Guidelines for Determining the Accuracy of Student Achievement Scores*, will assist in the proper interpretation of these results (See Appendix 3).

All of the questions were related to the six content domain areas selected for the Review and were also classified by process level (Knowledge, Application, or Higher-Order Skills). Each booklet contained a different group of attitudinal questions related to the following areas:

- student activities in the laboratory,
- science and chemistry as a career,
- the effect of science on society,
- the nature of science,
- specific aspects of the course in chemistry.

A complete list of questions found in each booklet is found in Appendices 1 and 2. Students were permitted access to calculators, mathematical instruments and trigonometric tables during the review process. A Periodic Table of the Elements was also supplied for each student.

3.3 Reliability and Validity of the Instruments

When the questions were selected for the student assessment section of the review, consideration was given to both reliability and validity. **Reliability** refers to the consistency of responses to these questions from day-to-day or, in the case of multiple-matrix-sampling, the consistency of responses to a set of items by a sample of students within a school. **Validity** refers to the degree to which the questions seem to be measuring what they are supposed to assess. A variety of methods can be used to determine both reliability and validity.

Reliability of the Questions

Information from both the results of the review, and from the OAIP Field Trials indicate that students responses to the items were indeed reliable. Field Trial p-values compare very well with Review p-values for those questions which were included in both surveys. Further indication of reliability is the fact that schools that did well on some questions did well on them all, while the converse was also observed. In addition, the scores obtained by schools and school boards were reliable as were the differences between them.

Validity of the Items

Evaluation of the validity of questions always involves a degree of judgement on the parts of those using the questions. The individuals responsible for selecting the questions were all experienced classroom teachers of Chemistry and chose questions from the OAIP Pool that, in their judgement, would assess achievement in each of the content domains and in each process skill. Educators have the responsibility to pursue the questions found in any assessment instrument to determine the curricular validity of the questions for their jurisdiction. While all of the content domains were core to both the existing and new guidelines, the local frameworks within which they are presented may vary.

4. OVERVIEW OF RESULTS AND PARTICIPATION RATES

4.1 Plan of Presentation

This report presents all of the data collected from the provincial sample for the Provincial Review in Chemistry which included 312 chemistry teachers and 11 169 students from 187 schools. The participants were selected from a total English-language population of 580 schools, 970 teachers and 55 000 students involved in the Senior Division Advanced-Level Chemistry course.

All French -language schools in which Senior Division Advanced Level Chemistry was taught also participated in the Provincial Review. The results from these 40 schools, 44 teachers and 1248 students are presented in the French-language *Senior Division Advanced Level Chemistry - Educators' Report.*

The displays in this report illustrate the results from the provincial sample. All of the displays found in school and board reports contain the same kinds of data found in the provincial report and are numbered identically. Display 1 in these results, for example, contains the same kind of data (Participation Rates) as Display 1 in school and board reports. The use of the common numbering scheme allows the comparison of the three levels of results.

4.2 Provincial, Board and School Results

For schools and school boards who participated in board reviews, student data collected are reported at the school, board, and provincial level. Board results contain the data collected from stu-

dents aggregated at the board level; that is, all the data from the students in the school board are presented as a whole. This data includes student background information, achievement, and attitude results.

Teacher data, except for the summary graphs concerning student opportunity-to-learn, as well as all information provided by the department heads concerning curriculum management, are to be found at the board and provincial level. No data of this type was reported at the school level.

Schools and school boards will be able to use the data collected to identify strengths and weaknesses in their programs. It is hoped that the data will stimulate useful discussion among science educators as they continue the implementation of the new science guideline. Individual school boards who opted for a board review are expected to analyze and interpret board data and to report publicly on the results. Comparison of individual schools is NOT appropriate.

All of the data collected from the provincial sample is presented in this provincial report. Display 68 provides details concerning the kinds of results reported at the school, board, and provincial levels.

Without the high degree of cooperation given by the many teachers, students and administrators who participated, this review could not have taken place. The professional approach of the educators of Ontario in responding to and administering the review was greatly appreciated.

4.3 Participation Rates

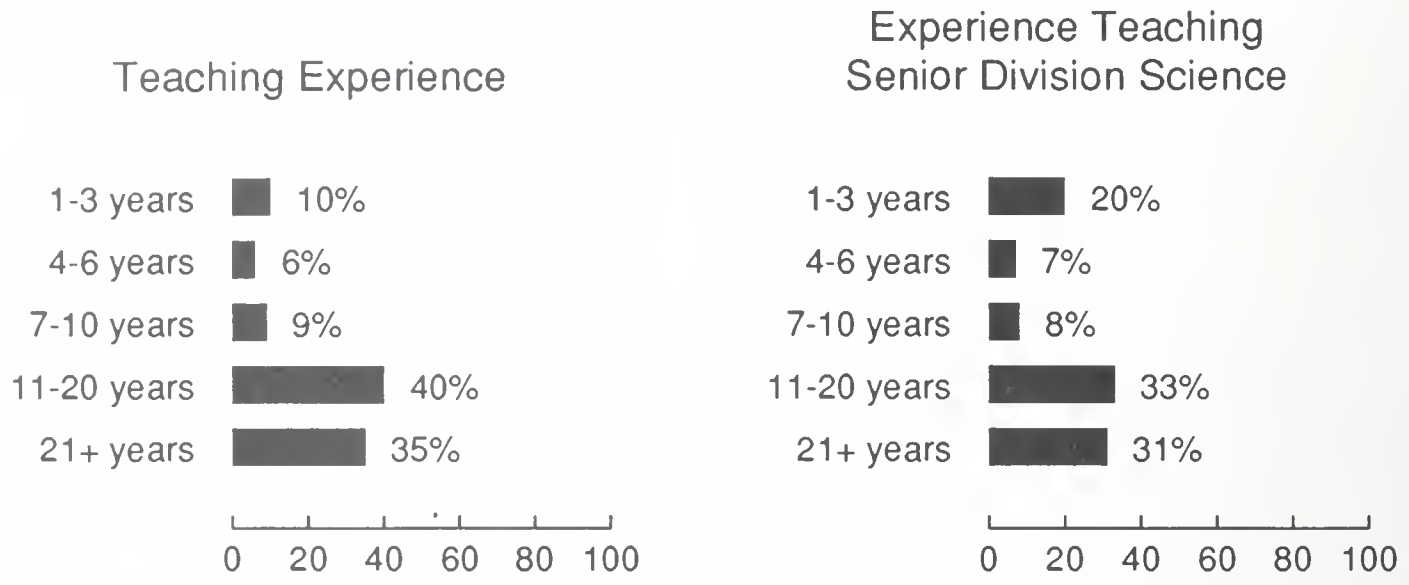
The Department Head in each participating school provided information through means of the

Display 1
Participation Rates
Provincial Results - Chemistry

Instrument	*Number Eligible*	*Number Returned*	*Return Rate (%)*
Course of Study (SCH)	100	91	91
Curriculum Management (SCH)	184	181	98
Teacher Data Questionaire (T)	312	309	99
Teacher Practices Questionaire (T)	312	300	96
Student Opportunity-To-Learn Form (T)	312	293	94
Student Assessment Booklets (Sets) (S)	312	309	99

Level at Which Data Was Provided SCH=School T=Teacher S=Student

Display 2
Percentage of Teachers with Varying Years of Teaching Experience and Experience Teaching Senior Division Science
Provincial Results - Chemistry



Curriculum Management Questionnaire. Each teacher of chemistry was asked to complete a Teacher Data Questionnaire, a Teacher Practices Questionnaire, and a Student Opportunity-To-Learn Form. Students completed Student Assessment Booklets.

Display 1 provides the number of eligible schools and teachers in the provincial sample, the number of questionnaires returned, and the percent returned. The number of eligible Curriculum Management Questionnaires indicates the number of schools in the provincial sample offering Senior Division Advanced Level Chemistry either during the second semester or as a full-year course. The participation rates are very high, indicating that the results obtained are representative of the students and teachers in the province.

5. THE TEACHER OF SENIOR DIVISION CHEMISTRY

A number of displays provide information about the qualifications and experience of Ontario's teachers of Senior Division Advanced Level Chemistry.

5.1 TEACHING EXPERIENCE

Display 2 shows the range of teaching experience among teachers as well as the amount of

accumulated experience teaching Senior Division Advanced Level Chemistry.

The display shows that chemistry teachers in Ontario are quite experienced, with more than 3 teachers in 4 having in excess of 10 years of teaching experience. It also demonstrates that some new science teachers are beginning to enter the profession after a period in which few new teachers began teaching. One consequence of this age distribution will take place in the few years following 1995, during which a large number of the teachers now teaching chemistry will retire.

The data also indicates that a significant number of these experienced teachers have less experience teaching senior division science than number of years in the profession. This may indicate an increase in the number of "cross-over teachers", that is, teachers of other subjects who teach in other subject areas due to changes in enrolment patterns.

5.2 BACKGROUND AND QUALIFICATIONS

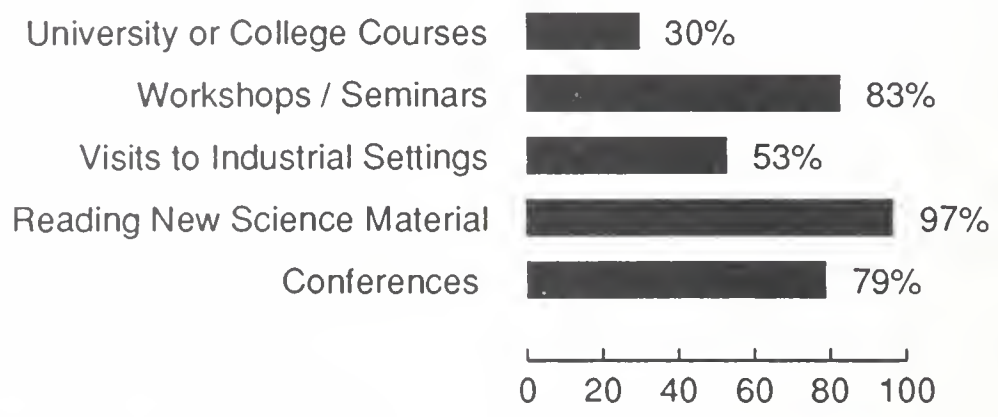
Display 3 provides a variety of information detailing teachers' educational background in science and the percentage of the provincial sample's teachers of chemistry who have obtained

Display 3
Teachers' Reports of Their Educational Background and Special Qualifications
Provincial Results - Chemistry

Science Background	*Courses*
Average Number of Year Long Chemistry Courses in Post Secondary Education	8.7
Average Number of Year Long Physics Courses in Post Secondary Education	2.8

Special Qualifications	*Percentage*
Teachers with Specialist Qualifications in Chemistry	54
Teachers with Specialist Qualifications in Physics	31
Teachers with Graduate Degree in Chemistry	9
Teachers with Graduate Degree in Physics	3
Teachers with Graduate Degree in Education	35

Display 4
Percentage of Teachers Using Various Methods for Keeping Science Knowledge Up-to-Date
Provincial Results - Chemistry



special qualifications. These special qualifications include specialist qualifications as well as graduate degrees in chemistry and education. Only 54% of teachers have specialist qualifications in chemistry. This compares to 75% reported in the 1983 OAIP Field Trials. This may be due in part to the fact that OAIP Field Trials included Grade 13 (OAC) teachers as well as those in the Senior Division. It may also be partly due to the retirement of a number of senior teachers. Chemistry teachers have taken an average of nearly 9 year-long chemistry courses in post-secondary education, as well as a substantial number of physics courses.

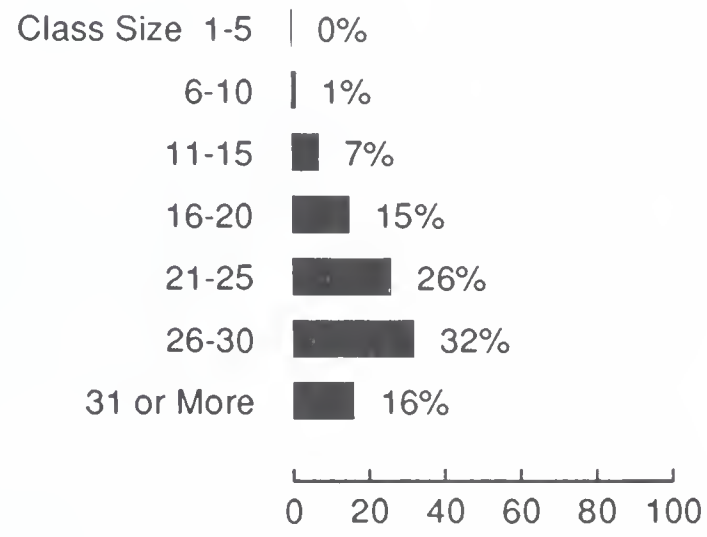
5.3 PROFESSIONAL DEVELOPMENT

Teachers, like most professionals, use a variety of methods to keep their science knowledge up-to-date. **Display 4** indicates the percentage of teachers who have involvement in various professional development activities. Almost all teachers read new science material as a means of keeping current, and a large majority attend conferences, workshops and seminars. Science in general, and chemistry in particular, is an area of study which is constantly changing. New research, innovative developments and changing approaches to science curriculum demands a high degree of flexibility and current awareness on the part of science teachers.

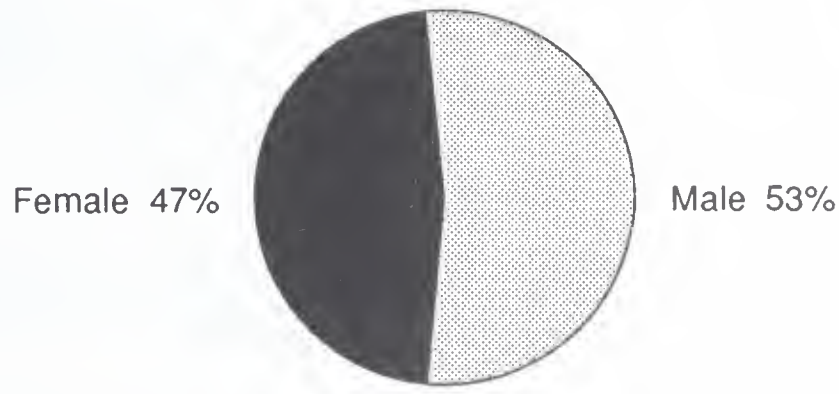
5.4 CLASS SIZES

Teachers also reported the number of sections they were currently teaching and the enrolment of each. The percentage of classes taught at various enrolment sizes in the provincial sample are presented in **Display 5**. Most of the classes are

Display 5
Percentage of Classes Reported
Taught at Varying Class Enrollments
Provincial Results - Chemistry



Display 6
Percentage of Gender Enrollment
in the Senior Division Advanced Level Science Course
Provincial Results - Chemistry



reported to have enrolments between 26 and 30 students. Sixteen percent of teachers reported that their classes had more than 31 students.

Information about teacher instructional practices and content coverage is presented in the section concerned with the implemented curriculum which follows later in these results.

6. THE STUDENT OF SENIOR DIVISION ADVANCED LEVEL CHEMISTRY

To obtain a profile of the student enrolled in advanced level Senior Division Chemistry, students answered questions about their interest in science, extracurricular science pursuits, and classroom activities. They also provided information about amount of homework assigned plans for further education use of computers in their school and at home the amount and type of employment the everyday activities which take place in their chemistry classrooms.

6.1 Gender Enrolment in the Chemistry Course

Display 6 presents the percentage of males and females enrolled in the provincial sample's Senior Division Advanced Level Chemistry course. Nearly half of the students are female, an encouraging support of efforts to encourage young women to continue with science courses in secondary school. The OAIP Field Trials found a very significant drop in the percentage of females enrolled in the sciences at the Grade 13 (OAC) level.

6.2 Student Plans for Post-secondary Education

One consideration that enters into the interpretation of these results is the plans of students for post-secondary education. **Display 7** shows both students' intentions to pursue science beyond secondary school as well as the number of science courses they expect to take as part of this further education. One graph shows the percentage of students indicating each of the possible response options ranging from no plans for further education through more than 4 years. While 42% plan for a traditional 3-4 year post-secondary education, a full 40% are expecting to pursue education beyond the traditional undergraduate program.

The other graph shows the percentage of students indicating various plans for taking science courses. More than half expect to take further science courses, while 23% are as yet undecided.

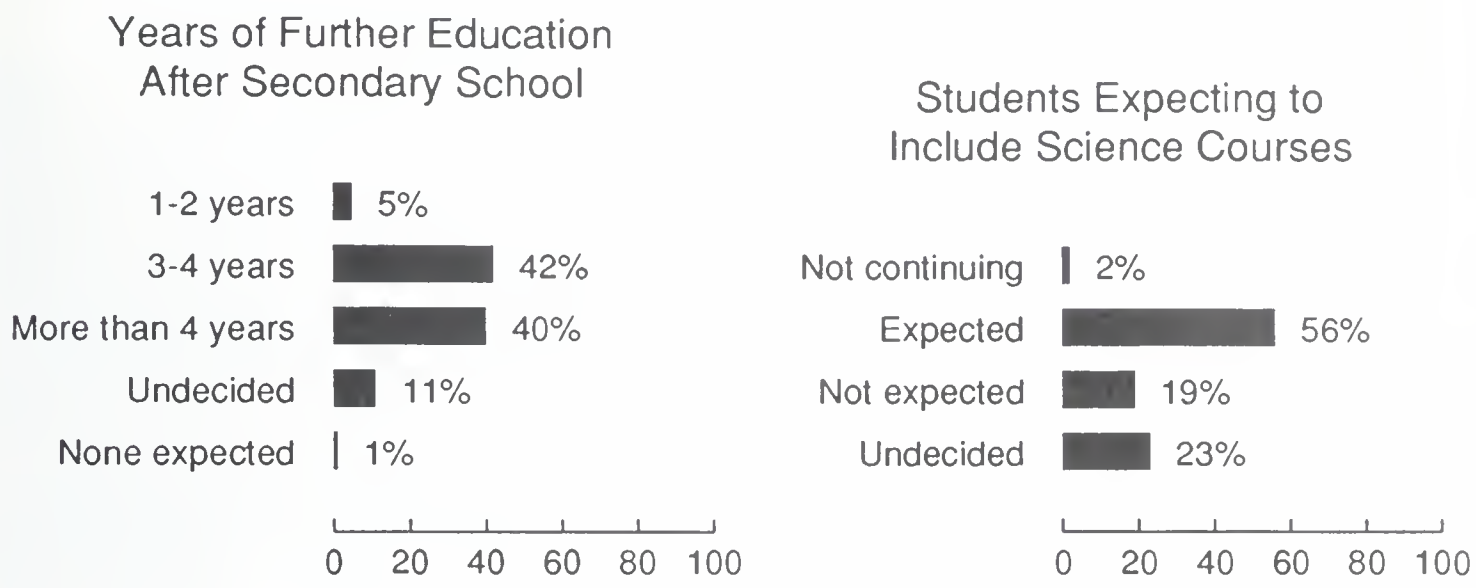
6.3 Student Use of Computers at Home and in School

Many students have access to computers, both at home and in school. Students provided information on whether they had a computer at home and if so, the uses they made of it. Students also indicated the amount of time they used a computer at school, not necessarily only in science classes. **Display 8** shows that half of the students report a computer at home, and of these, half use it for a multitude of purposes. Computer use in the classroom is very low, with 67% reporting no use of the computer at school.

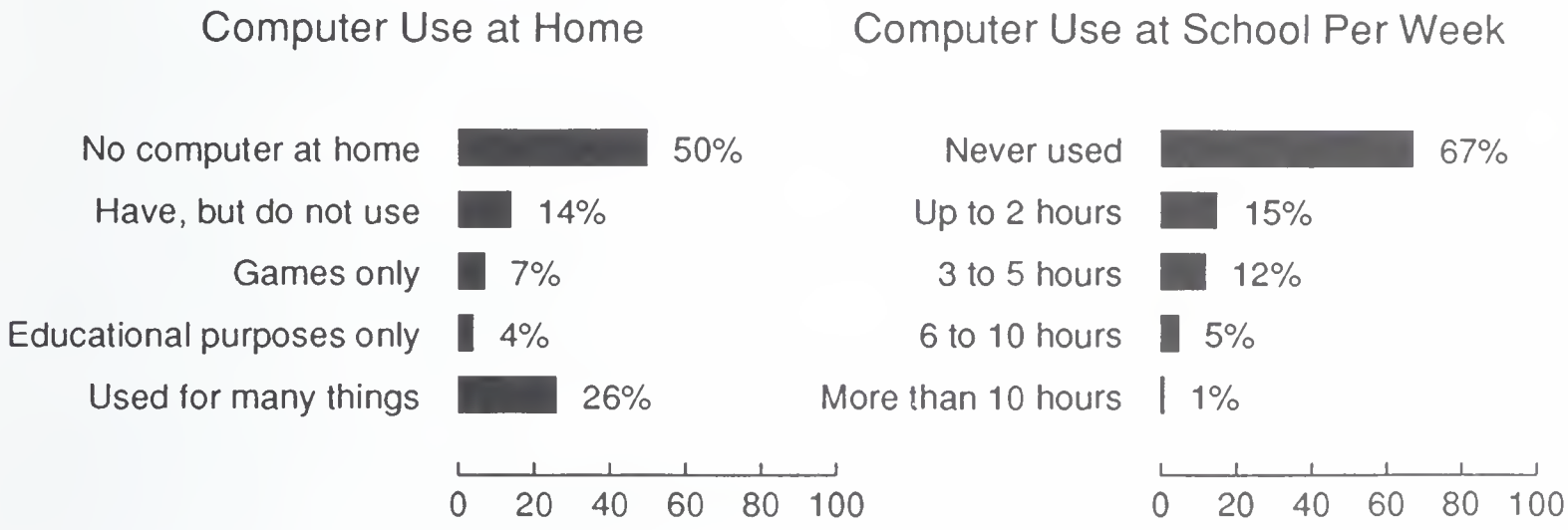
6.4 Science Activities in the Classroom

The greatest exposure that students usually have to science in general, and chemistry in particular, takes place in the classroom. Students' reports of

Display 7
Student Reports of Future Educational Plans
and Whether Science Courses Are Included in These Future Plans
Provincial Results - Chemistry



Display 8
Percentage of Students Reporting Use of a Computer
for Various Activities at Home and Hours of Use of a Computer at School
Provincial Results - Chemistry



Display 9
Students' Reports of Frequency of Various Classroom Activities
Provincial Results - Chemistry

Classroom Activity	*Frequency of Occurrence*				
	4 Times Per Wk.	*3 Times Per Wk.*	*Twice Per Wk.*	*Once Per Wk.*	*Never*
How often does the teacher do demonstrations?	2	10	30	52	6
How often does the teacher distribute notes?	17	19	21	25	18
How often does the class copy the teacher's notes from the chalkboard/ overhead projector into notebooks?	43	27	16	11	3
How often does the class work in small groups (2 to 5 students) to do experiments?	3	10	28	52	6
How often do members of the class do experiments in science individually (without any lab partners)?	1	1	2	11	87
How often do members of the class use a computer?	1	1	1	5	92
How often does the teacher use the students' ideas and suggestions when planning science lessons?	2	3	7	23	65
How often does the class use library or resource books?	2	3	5	23	66

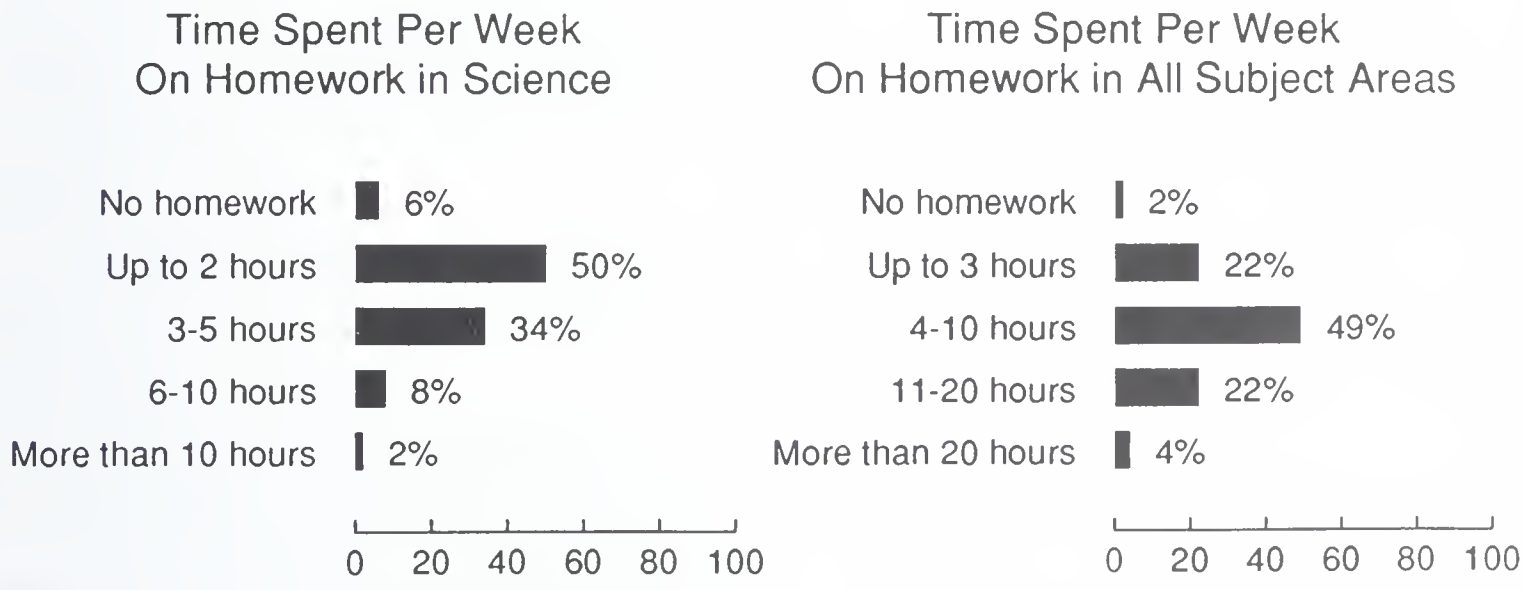
activities are an important window into their perceptions of science and how it is taught and learned. **Display 9** presents students' reports of their activities and includes a range of activities from teachers doing experiments, distributing notes, through student activities such as working in small groups or using library books and resources. Although a variety of activities are reported, traditional ones prevail. The most frequent activity reported by far was copying notes from the chalkboard/overhead projector into notebooks. Very infrequent use of computers, libraries and student suggestions was reported. More than half of the students reported experimental activity less than twice a week.

The new guideline both suggests and prescribes a number of teaching and learning activities. Specific student activities are mandated in each unit of the new course. Teachers are also encouraged to make use of such facilities as libraries and computers. The use of independent study and cooperative learning is also encouraged.

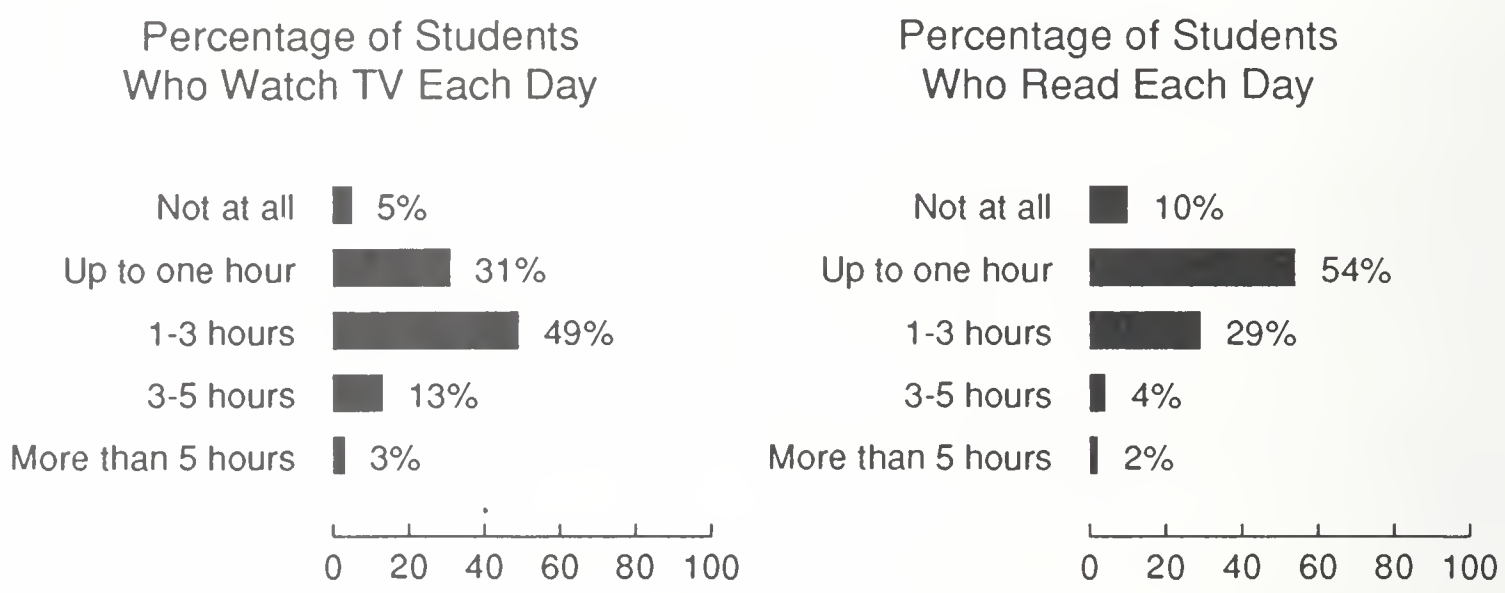
6.5 Student Homework

Display 10 shows student reports of the number of hours spent per week on homework in science and other courses. Students indicated the amount of time spent on homework for the chemistry course as well as for homework in all subjects, including science. Students spend more than two hours per week on chemistry, and most spend from 4-10 hours per week on all subjects.

Display 10
Student Reports of Number of Hours Spent Per Week on Homework in Science and Homework in All Subject Areas
Provincial Results - Chemistry



Display 11
Percentage of Students Reporting Varying Amounts of Television Watching and Reading Each Day
Provincial Results - Chemistry


Percentage of Students Who Watch TV Each Day
Not at all 5%
Up to one hour 31%
1-3 hours 49%
3-5 hours 13%
More than 5 hours 3%
0 20 40 60 80 100
Percentage of Students Who Read Each Day
Not at all 10%
Up to one hour 54%
1-3 hours 29%
3-5 hours 4%
More than 5 hours 2%
0 20 40 60 80 100

6.6 Reading and Watching Television

Display 11 compares students' use of leisure time, specifically in watching television and reading. The percentage of students' indicating the various response options are provided for both watching television and reading. Few students watch television more than three hours a day, while 35% read more than one hour per day.

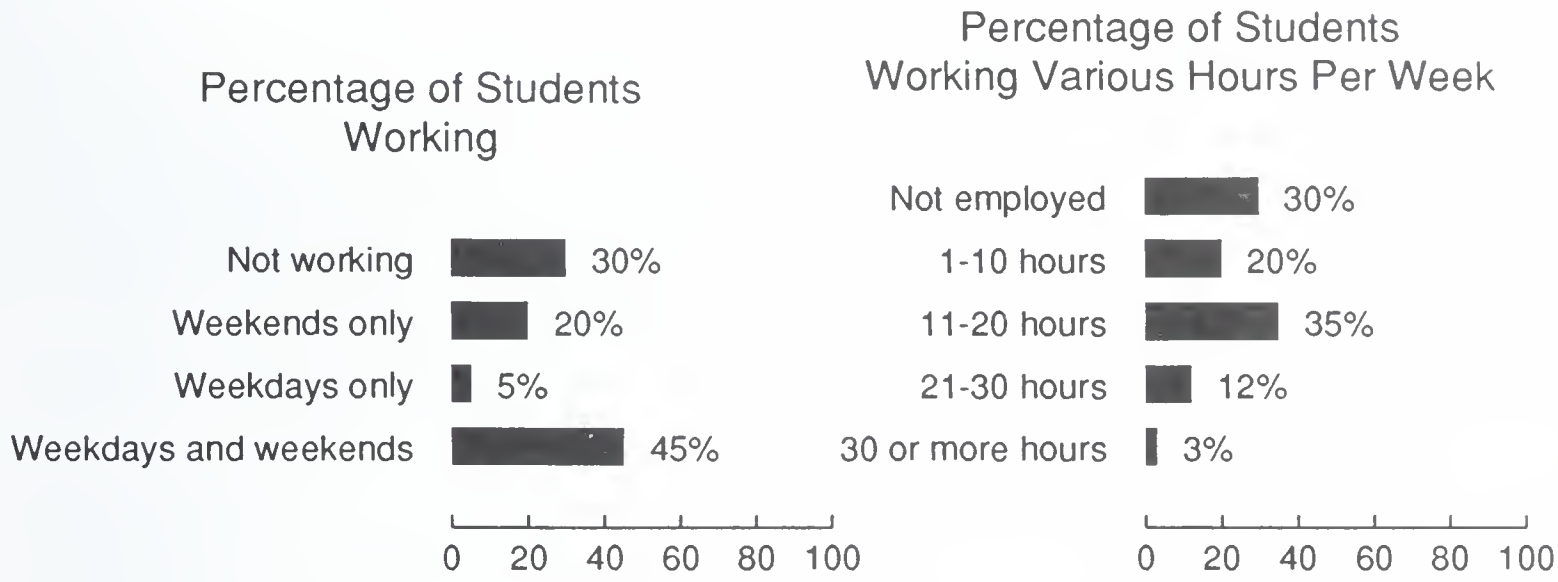
6.7 Student Employment

Students frequently hold outside employment during the school year. **Display 12** shows that 70% of students have a job, and half of these work more than 10 hours per week.

6.8 Out-of-School Science Activities

Science education is not limited to the classroom. Students always have the opportunity to read about science in magazines and in newspapers or watch science programs on television. **Display 13** shows the percentage of students reporting their out-of-school involvement with science. Roughly 40% of students read about science in the professional and popular media, and about half view television programs with a focus on science.

Display 12
Percentage of Students Reporting Various Employment Activities and Number of Hours Spent Per Week Working
Provincial Results - Chemistry



Display 13
Percentage of Students Reporting Various Out-of-School Activities Concerned With Science
Provincial Results - Chemistry

Out-of-School Activities	*Often*	*Sometimes*	*Rarely*	*Never*
Reading About Science in a Newsweekly	6	29	38	27
Reading Science Magazines	11	30	32	27
Reading About Science in the Newspaper	8	37	37	18
Watching Science Programs on Television	15	36	28	20

6.9 Science Fairs

Students indicated whether their schools held science fairs and the extent of their participation in such activities.

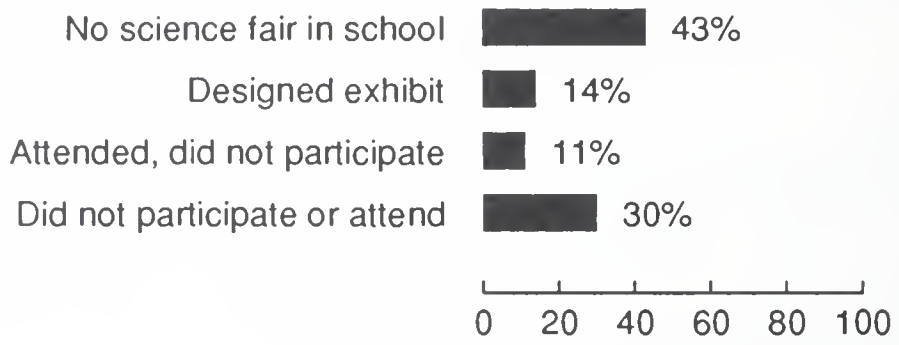
Display 14 reports that just under 60% of schools hold science fairs and 14% of the students involved in the chemistry course participated in them.

Information concerning students' attitudes towards science and careers in science are described in the section concerned with the attained curriculum together with results of performance on the student achievement measures.

7. THE INTENDED CURRICULUM

The main source of the intended curriculum in Ontario is the Ministry of Education Guideline. The curriculum for Senior Division Advanced Level Chemistry is currently in transition. Since 1966 the curriculum has been defined by *Curriculum S-17D: Chemistry Senior Division, Grade 12 Five Year Program.* In 1987 a new curriculum was released: *Science, Intermediate and Senior Divisions 1987, Part 13 Chemistry Grade 11 Advanced and OAC.*

Display 14
Percentage of Students Reporting Various Levels of Involvement in School Science Fairs
Provincial Results - Chemistry



While implementation of the new guideline is not required to begin until September 1989, many teachers have already begun the process. Therefore achievement questions were chosen to reflect aspects of content and skills common to both guidelines.

School or board-developed courses of study represent another level in the intended curriculum. This review examined courses of study obtained from a sample of Provincial Review Schools. Also, teachers in both the provincial review and all board reviews answered questions about their school's course of study.

7.1 Courses of Study

As part of the assessment of the intended curriculum at the provincial level, a sample of 100 schools provided courses of study to the Ministry which were examined by a team of Ontario chemistry educators.

The transition between two guidelines posed a problem for the course of study analysis team. Many of the courses were based upon Guideline S-17D (1966), in which there is no indication of requirements for courses of study. However, Part I of the new Intermediate/Senior Science Guideline (Program Outline & Policy) is quite specific in describing requirements for courses of study. To provide a common set of criteria that was applicable to both guidelines it was decided that the requirements described in OS:IS would form the basis for the analysis. A number of criteria were established. These included:

- an indication of level of difficulty and credit value,
- the inclusion of a description of general course objectives, teacher methods, and expected student outcomes.
- the presence of objectives for units, -the inclusion of attitude, knowledge and skill objectives,
- the specification of core content,
- an indication of evaluation practices and course resources.

Display 15 presents the results of this analysis.

Source and Credit Value

Most schools indicated the guideline and the credit value. All schools indicated the appropriate level of difficulty, either as separate statement or in the course code (eg SCH 3A1). Where a guideline (as the source document for the development of the course of study), was not indicated, the analysis team attempted to relate the content to the old or new guidelines to determine which was used as the basis for the course of study.

Objectives and Outcomes

Most courses of study indicated the general aims for the whole course, although the terminology used to describe this section varied greatly from "course objectives", to "course aims" to "rat onale". Generally, course objectives were stated in terms of teacher methods and content direction. Some teachers indicated objectives, especially fopr units, in terms of student behaviours rather than teacher objectives. However, it was noted that the attitudinal objectives in the new science guidelines were often not included if detail was provided in terms of student behaviour.

Few courses of study included unit objectives. Where these were indicated, the emphasis was on the knowledge objectives with some skills indicated and few, if any, attitudinal objectives. Every course of study provided a list of core content, often expanding upon the core content listed in the old guidelines.

Sequence

If a specific sequence was not noted, it was implied that the course content was taught in the order in which it was presented. Although not a requirement in OS:IS, timing was noted in the analysis of the courses of study as a method of validating the correlation between the questions asked in the student assessment section of the review and the content. Timing was indicated in

Display 15
Analysis of the Courses of Study:
Percentage of Schools Containing Various Components
Provincial Results – Chemistry

Course Description			
Which guideline was in use?	Old 42%	New 31%	Not Noted 27%
Was level of course difficulty indicated?	Yes 97%	No 3%	
Was the credit value indicated?	Yes 67%	No 33%	
Course Objectives			
Were general course aims included?	Yes 57%	No 43%	
Were teacher methods/directions/suggestions included?	Yes 67%	No 33%	
Were student behaviours/outcomes included?	Yes 75%	No 25%	
Unit Objectives			
Were unit objectives included?	All 70%	Some 1%	Not Noted 29%
Were attitude objectives included?	Yes 47%	No 53%	
Were knowledge objectives included?	Yes 80%	No 20%	
Were skills objectives included?	Yes 82%	No 18%	
Core Content			
Was core content listed in course of study?	Yes 97%	No 3%	
Was the sequence of the course indicated?	Stated 22%	Implied 78%	
Was the time of units included?	Yes 81%	No 19%	
How many units of the provincial review were included in the Course of Study?	Five 2%	Six 98%	
What was the approximate time devoted to the six units?	Mean 88%		Not Noted 16%
Evaluation Practices			
Were the evaluation practices for the whole course stated?	Yes 60%	No 40%	
Were the evaluation practices for individual units stated?	Yes 46%	No 54%	
Were evaluation practices for knowledge objectives and/or strategies stated?	Yes 11%	No 89%	
Resources			
Were texts indicated?	Yes 69%	No 31%	
Were other learning materials indicated?	Yes 77%	No 23%	

Display 16
Percentage of Teachers Reporting Inclusion of Various Components in Their School Course of Study and the Amount of Influence of These Components on Their Teaching
Provincial Results - Chemistry

Course of Study Components	*Percentage Which Included Components*	*Degree of Influence Upon Teaching*		
		None	*Some*	*Much*
Rationale	79	27	50	23
Course Aims	87	16	33	51
Instructional Objectives	87	14	16	70
Sequence and Timing of Objectives	91	13	37	50
Special Features (safety, sex equity, etc.)	76	26	41	33
Teaching Strategies	72	29	31	40
Textbooks and Other Resources	91	13	43	43
Student Evaluation Techniques	81	20	33	47

Units

The six units involved in the student assessment section of the Provincial Review were included in most courses of study. Occasionally, additional optional units were included; however, in general, the six units used in the review accounted for over 90% of class time.

Evaluation Practices

Most courses of study stated a "marks breakdown", indicating how much emphasis was placed on term work and examinations. Very few indicated evaluation practices for individual units; where these did occur, the practice was often linked to the use of the new guideline. A few courses of study linked evaluation practices to objectives and strategies such as laboratory reports. The courses of study which indicated objectives in terms of student behaviours or outcomes were most likely to indicate evaluation practices associated with objectives and strategies.

Textbooks and Resources

Most of the courses of study indicated the textbook which was used; however, very few of the courses of study mentioned resources as a separate category. Often the resources were implied or stated as a part of the strategies described.

The courses of study submitted for analysis varied greatly in length and in the kind of materials included. Occasionally, schools in large boards submitted what might be referred to as "an outline of a course of study" - a two or three page summary providing the essential data and refer-

ring to a board document which provided much more detail. Several courses of study were "cut and paste" versions of teacher guidebooks associated with a particular textbook. Although very thorough, these lacked any indication of adaptation to the local needs of the school and students.

Some schools have obviously been implementing new programs based on draft copies of the new guidelines. Generally, these courses of study tended to be far more detailed and tended to relate objectives, strategies, evaluation techniques and resources in a meaningful and practical manner.

While only a sample of courses of study were examined by an analysis team, all teachers indicated whether various components were found in their courses of study, and the degree of influence of these components upon their actual instructional activities. (If a teacher said that the course of study did not contain the components the influence upon their teaching was coded as 'none'). **Display 16** provides the results for a variety of course components. The fact that the inclusion of "special features" is mentioned 76% of the time is an encouraging indication of the degree of implementation of the new guideline, as this component receives considerable emphasis in the new guideline. Special features include such important curriculum areas as: safety, sensitive issues, career awareness, and individualized instruction.

8. THE IMPLEMENTED CURRICULUM

The implemented curriculum can be best defined as "what happens in the classroom" the content covered and the methods by which teachers convey this content to the students. It also includes the kinds of resources teachers have available and use, the evaluation techniques instituted within the classroom, and very importantly, whether teachers have provided students with the opportunity-to-learn the content and skills required for successful completion of the actual assessment questions.

8.1 Hours Spent on Chemistry Topics

Six main chemistry topics delineated the content areas of this provincial review. In order to gauge the relative course emphases teachers indicated the number of hours spent on each topic. Their responses were placed into various categories and the percentage of teachers falling in each category in the provincial sample are presented in **Display 17**. The longest time was spent on Atomic Structure, closely followed by Gases and Mole Problems. It is interesting to note that student achievement in Atomic Structure was lowest of all content domains. An emphasis on atomic structure as a theoretical basis for explaining observations is characteristic of chemistry courses which were developed from the CHEMStudy approach. Curriculum S17-D was such a course. The new guideline places less emphasis on this aspect of chemistry.

Display 18 provides information concerning the range of time spent by teachers on these topics. Mean scores sometimes obscure degrees of variation (range). Such variation might be found among a group of teachers or among schools in time spent on a topic. A useful method to examine the range of time spent on topics is through the use of "box and whiskers" charts.

Using Display 18 as an example, the line drawn in the boxes for each of the content domains is the mid-score or median. Half of the teachers in the provincial sample reported spending more time than the median, and half reported spending less time on the topic. The box includes the middle 50% of the teachers, 25% immediately above, and 25% immediately below the median. The lines extending beyond the boxes indicate the range of scores for an additional 40% of the teachers 20% above and 20% below the box. Thus the box and lines (whiskers) represent 90% of the teachers in the province. The remaining 10% are "outliers",

with 5% above, and 5% below. Schools not involved in the provincial review might find box and whiskers charts useful in comparing themselves to the provincial sample.

8.2 Class Activities in Chemistry

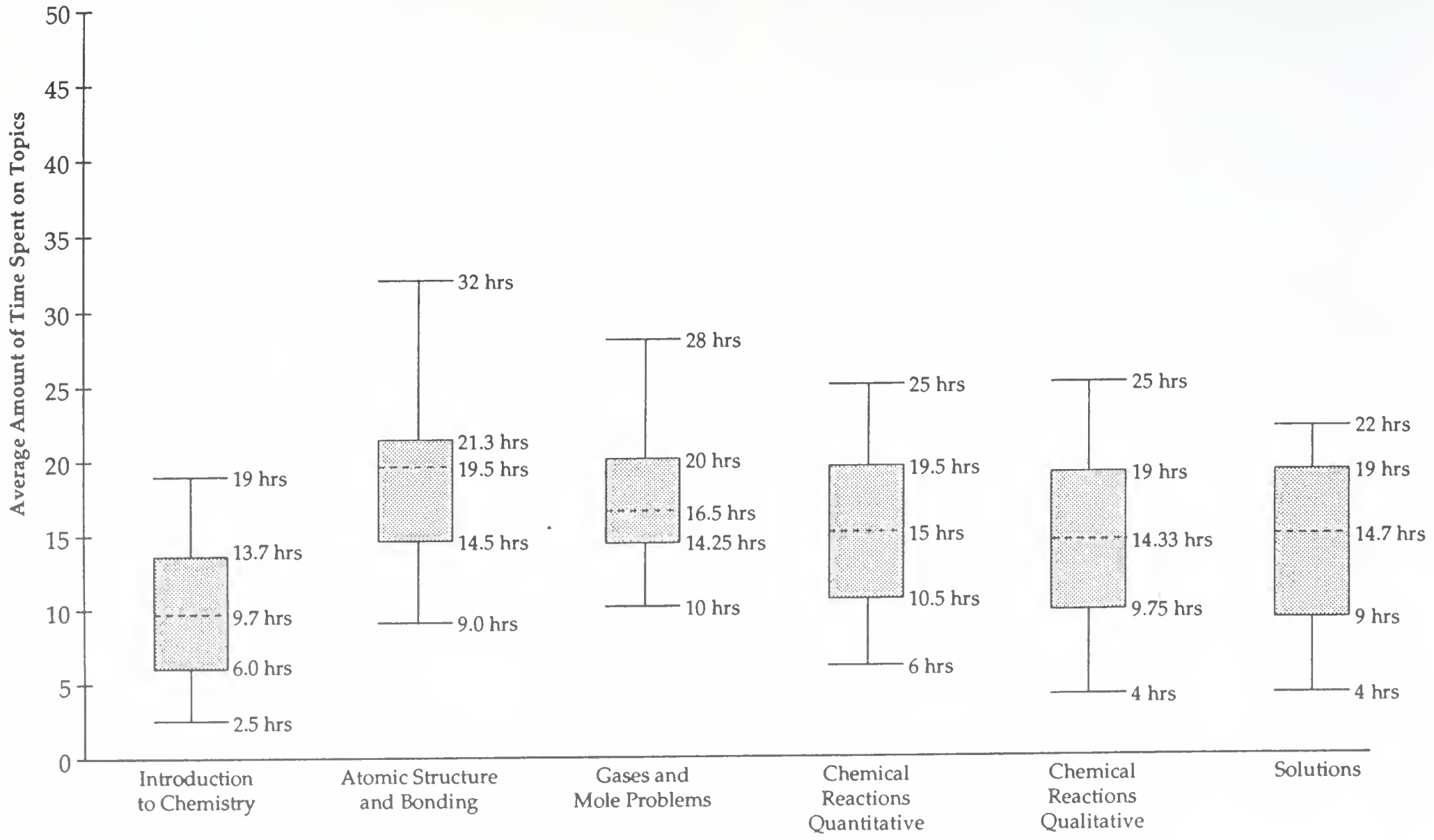
Class instructional time can be spent in a variety of ways including group or class discussions, teacher presentation, desk-work etc. Teachers approximated the percentage of time their classes were involved in these instructional activities. The figures in **Display 19** are the averages from the provincial sample. About half of the time spent in class might be classified as student centred. As implementation of the new guideline proceeds, mandated student activities and the recommendations for a variety of teaching approaches which emphasize both the content and the process of science, should increase this proportion of student-centred work.

Display 17
Percentage of Teachers Reporting Varying Number of Hours Spent on Topics
Provincial Results - Chemistry

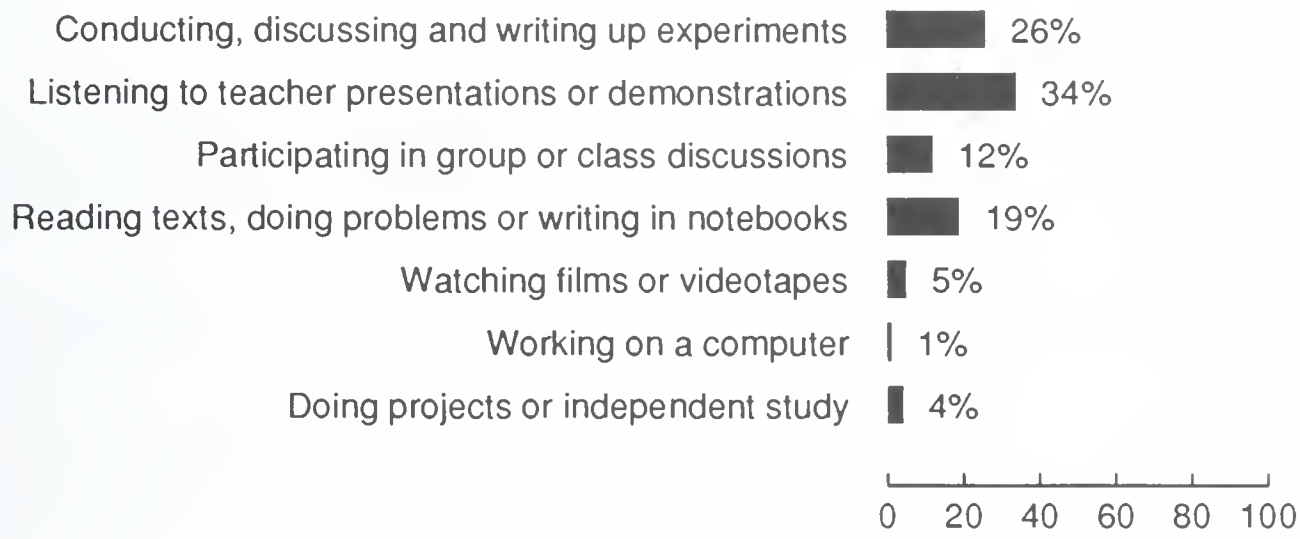
Chemistry Topics	*Number of Hours*							
	0	*1-5*	*6-10*	*11-15*	*16-20*	*21-30*	*31-40*	*41-50*
Introduction to Chemistry	1	24	36	25	14	1	0	0
Atomic Structure and Aggregates	1	2	10	25	37	19	6	1
Gases and Mole Problems	1	1	8	36	39	14	2	0
Chemical Reactions - Quantitative	1	4	22	29	32	12	1	0
Chemical Reactions - Qualitative	2	8	26	30	19	14	1	0
Solutions	1	11	21	26	35	7	0	0

Display 18

Variation Among Schools in Average Time Spent on Various Topics



Display 19
Teachers' Average Report of Percentage of Class Time Spent in Various Instructional Activities
Provincial Results - Chemistry



8.3 Student Opportunity-to-Learn

One of the best predictors of student achievement in large-scale surveys is the opportunity students have had to learn the content and skills required to answer the achievement questions. Teachers were asked to examine each student achievement question and indicate whether students had the opportunity-to-learn (OTL) the science necessary to answer the question correctly. Teachers did so by indicating whether the science necessary to answer the questions had been taught or reviewed, and if not, why not. If the teacher did not teach or review the science the teacher chose one of the following reasons for not doing so:

- taught prior;
- taught later in another course;
- not in the curriculum; or
- not taught for other reasons.

The data in these graphs is based upon the weighting of teacher responses by the numbers of students taught by each teacher. That is, in order to provide an accurate representation of the percentage of students who had received the opportunity-to-learn the science in the provincial

sample, the responses of teachers who taught larger numbers of students were given larger weights than those teachers reporting having taught fewer numbers of students. This weighting provides the most valid measure of this aspect of the intended curriculum.

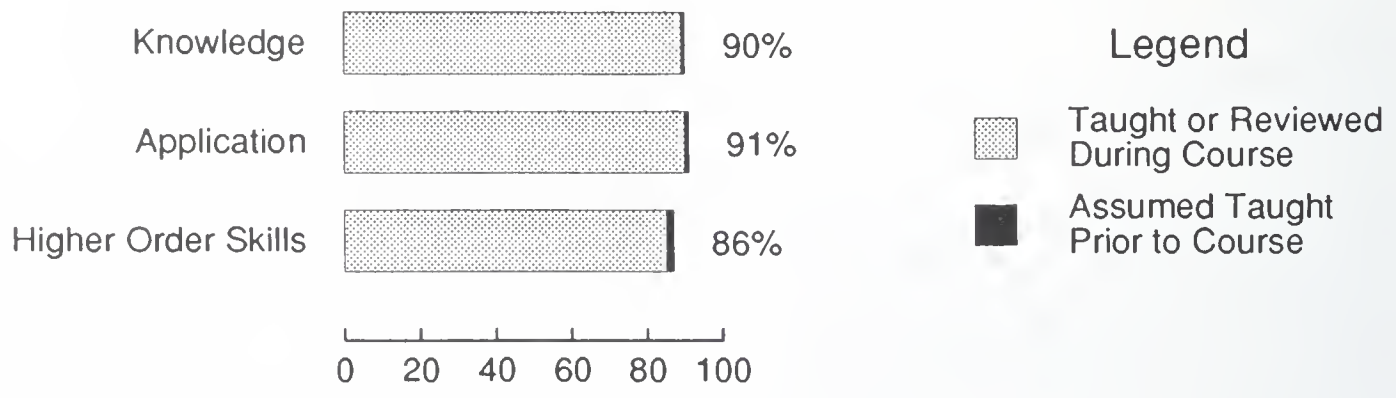
The displays associated with opportunity-to-learn (**Displays 20 through 25**) indicate a high degree of coverage for all areas. The lowest OTL was found in the Solutions content area, perhaps because it is often the last unit taught. In spite of the difficult timing of the review, and the great deal of material to be covered in the course, the overall message is that teachers of senior division chemistry cover nearly all of the implemented curriculum as measured by the questions on this review.

The results for the provincial sample for opportunity-to-learn are presented in a variety of ways. Three bar graphs in **Display 20** provide summary opportunity-to-learn data for questions grouped by process level. Three such levels were used in this review:

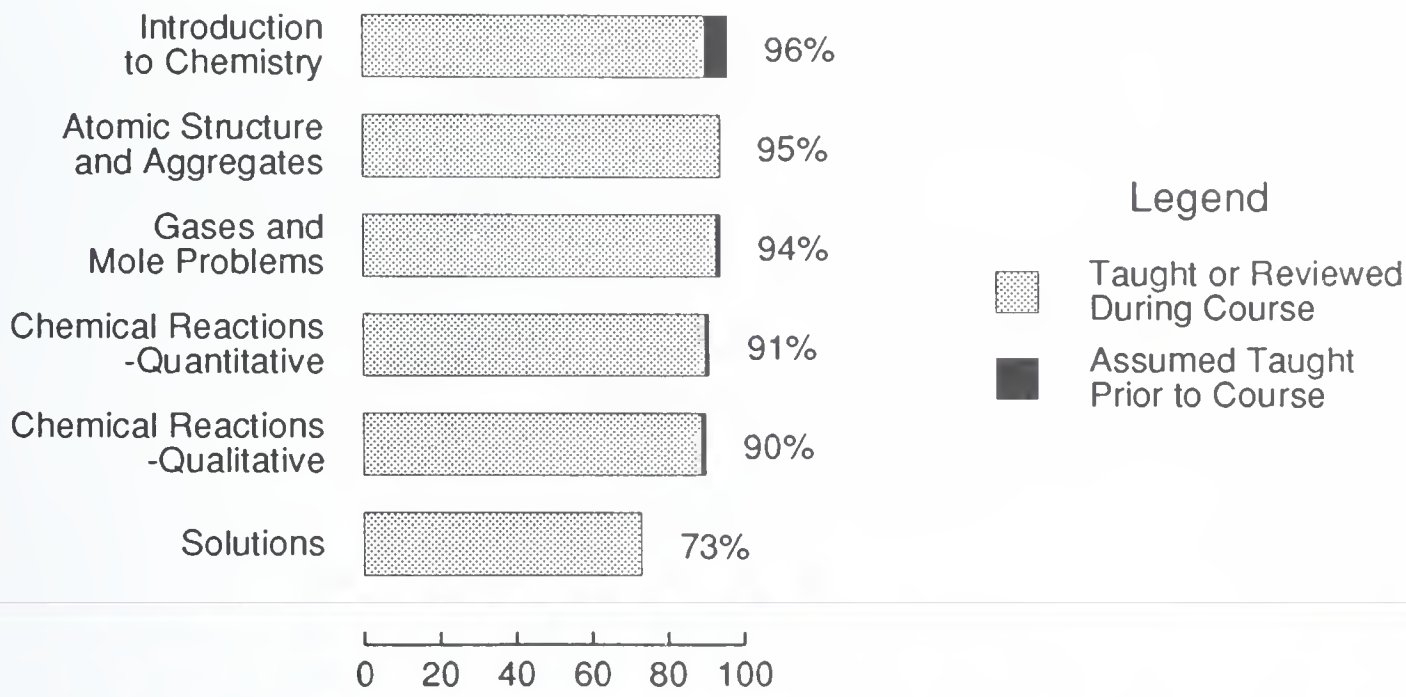
- Knowledge- questions that could be answered by recalling factual information.
- Application questions that required applications of factual information to new situations.
- Higher Order Skills questions that required several reasoning steps and/or the application of concepts from a number of areas of the course.

Display 21 provides summary opportunity-to-learn data for questions averaged by the content domain of the questions. The content domains and number of questions in each domain were:

Display 20
Percentage of Students Reported by Teachers as Having Had the Opportunity-to-Learn the Science Necessary to Answer the Questions Correctly by Process Level
Provincial Results - Chemistry



Display 21
Percentage of Students Reported by Teachers as Having Had the Opportunity-to-Learn the Science Necessary to Answer the Questions Correctly by Content Domain
Provincial Results - Chemistry



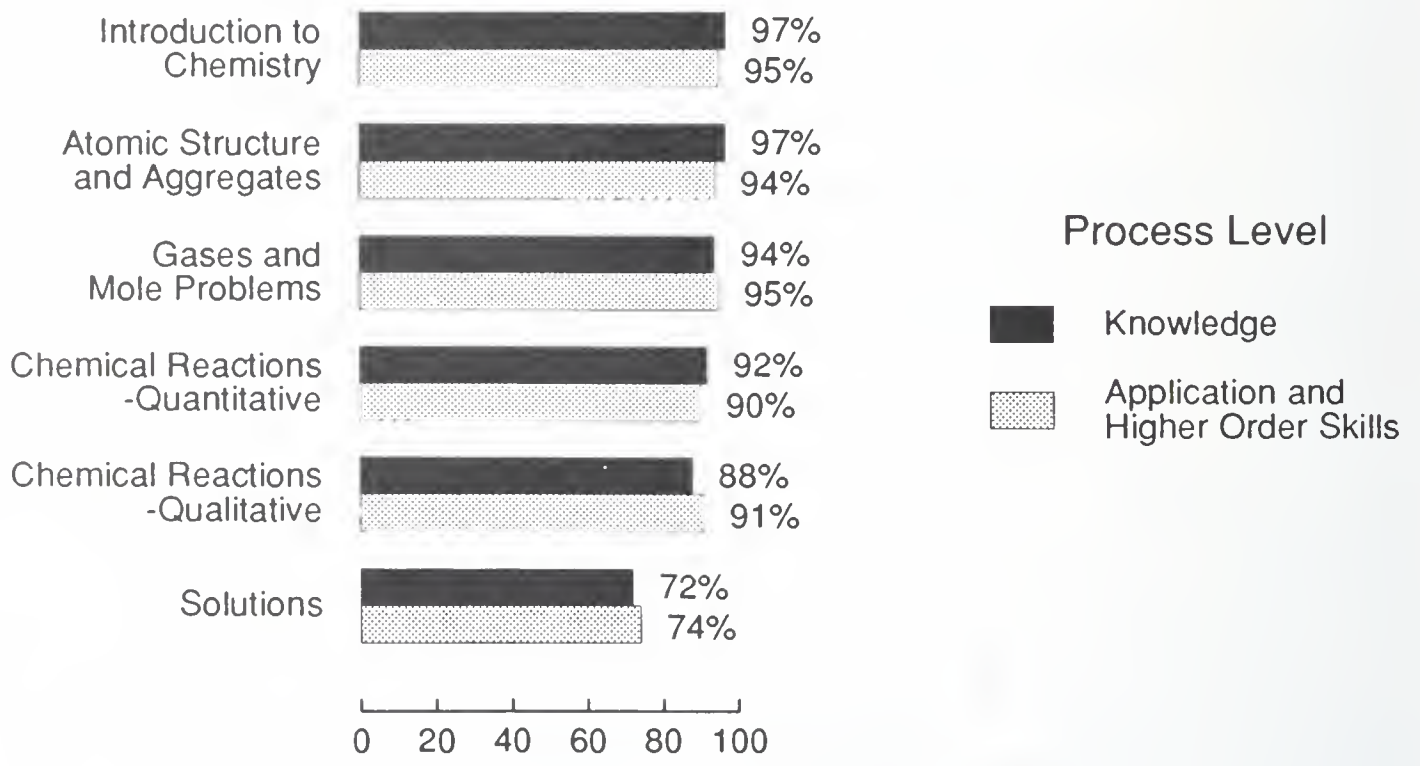
Introduction to Chemistry:	10 questions
Atomic Structure and Bonding:	20 questions
Gases and Mole Problems:	21 questions
Chemical Reactions-Quantitative	20 questions
Chemical Reactions-Qualitative	22 questions
Solutions	17 questions

Display 22 presents average opportunity-to-learn results for questions seen as calling upon either Knowledge or higher order operations (Application and Higher-Order skills combined). The bar for Knowledge presents average opportunity-to-learn for the 30 questions requiring chemistry knowledge, the bar for Application and Higher Order Skills does the same for the remaining 80 questions requiring higher order operations.

Display 23 presents data on opportunity-to-learn for each achievement question. The number of responding teachers in the provincial sample is indicated and the percentage giving each of the response options (taught or reviewed, taught prior, taught later, not in curriculum, and not taught for other reasons) is presented for each question.

Displays 24 and 25 provide information concerning the range among schools of reports of student opportunity-to-learn in the province.

Display 22
Percentage of Students Reported by Teachers as Having Had the Opportunity-to-Learn the Science Necessary to Answer the Questions Correctly, by Process Level and Content Domain
Provincial Results - Chemistry



Display 23
Percentage of Teachers Indicating Whether the Science Necessary to Answer Each Question Had Been Taught or Reviewed and if Not, the Reason for Not Teaching or Reviewing the Science
Provincial Results - Chemistry

Introduction to Chemistry / *Process Level*	*Item No.*	*Response Categories (Percentage of Teacher Responses)*				
		Taught or Reviewed	*Taught Prior*	*Taught Later*	*Not in Curriculum*	*Not Taught-Other Reasons*
Knowledge	7	90	3	3	3	2
	13	94	6	0	0	1
	44	94	2	1	0	3
	81	100	0	0	0	0
	97	98	1	0	0	0
Application	46	94	1	1	3	2
	63	58	32	3	5	1
	109	96	2	0	0	2
	121	86	9	1	1	2
Higher Order Skills	122	86	8	2	1	3

Display 23 (continued)
Percentage of Teachers Indicating Whether the Science Necessary to Answer Each Question Had Been Taught or Reviewed and if Not, the Reason for Not Teaching or Reviewing the Science
Provincial Results - Chemistry

Atomic Structure and Aggregates / *Process Level*	*Item No.*	*Response Categories (Percentage of Teacher Responses)*				
		Taught or Reviewed	*Taught Prior*	*Taught Later*	*Not in Curriculum*	*Not Taught-Other Reasons*
Knowledge	1	98	0	1	0	1
	42	100	0	0	0	0
	67	100	0	0	0	0
	98	93	0	4	1	2
	126	93	2	1	1	4
Application	5	98	0	1	0	1
	22	98	1	0	1	1
	34	93	0	2	1	3
	36	99	1	0	0	0
	62	93	0	5	1	0
	79	97	0	2	0	1
	96	97	0	2	0	1
	106	99	0	1	0	0
	123	99	1	0	0	0
	125	85	0	9	3	3
	128	93	0	3	1	3
Higher Order Skills	8	93	0	3	2	2
	69	98	0	1	0	1
	82	70	0	14	9	7
	124	94	0	3	1	1

Display 23 (continued)
Percentage of Teachers Indicating Whether the Science Necessary to Answer Each Question Had Been Taught or Reviewed and if Not, the Reason for Not Teaching or Reviewing the Science
Provincial Results - Chemistry

Gases and Mole Problems / *Process Level*	*Item No.*	*Response Categories (Percentage of Teacher Responses)*				
		Taught or Reviewed	*Taught Prior*	*Taught Later*	*Not in Curriculum*	*Not Taught-Other Reasons*
Knowledge	12	88	1	3	1	8
	38	88	10	1	1	1
	74	93	1	3	0	3
	105	92	1	2	0	5
	134	95	1	1	0	3
	135	96	0	1	0	3
Application	2	99	0	0	0	1
	15	95	0	2	0	3
	35	93	1	3	0	4
	37	94	1	3	0	3
	72	94	1	3	0	3
	93	94	1	2	0	3
	102	93	1	3	0	3
	107	92	1	3	0	4
	129	100	0	0	0	0
	142	93	0	1	1	5
Higher Order Skills	14	93	1	3	0	3
	31	93	0	3	0	3
	75	93	1	3	0	3
	112	93	1	3	0	3
	138	89	2	3	1	5

Display 23 (continued)
Percentage of Teachers Indicating Whether the Science Necessary to Answer Each Question Had Been Taught or Reviewed and if Not, the Reason for Not Teaching or Reviewing the Science
Provincial Results - Chemistry

Chemical Reactions -Quantitative Process Level	*Item No.*	*Response Categories (Percentage of Teacher Responses)*				
		Taught or Reviewed	*Taught Prior*	*Taught Later*	*Not in Curriculum*	*Not Taught-Other Reasons*
Knowledge	10	96	1	0	1	1
	45	86	1	3	1	9
Application	11	74	10	4	2	10
	18	98	0	1	0	1
	48	98	0	0	0	1
	49	98	0	0	0	1
	51	98	0	0	0	1
	61	99	0	1	0	1
	77	97	0	1	0	2
	92	90	1	3	0	7
	94	90	1	3	1	6
	130	98	0	0	0	1
	132	99	0	0	0	1
	133	91	1	2	1	6
	140	92	1	2	0	5
Higher Order Skills	17	93	0	2	1	3
	52	76	0	7	3	15
	64	48	1	25	13	13
	91	88	1	4	1	6
	131	80	2	5	1	11

Display 23 (continued)
Percentage of Teachers Indicating Whether the Science Necessary to Answer Each Question Had Been Taught or Reviewed and if Not, the Reason for Not Teaching or Reviewing the Science
Provincial Results - Chemistry

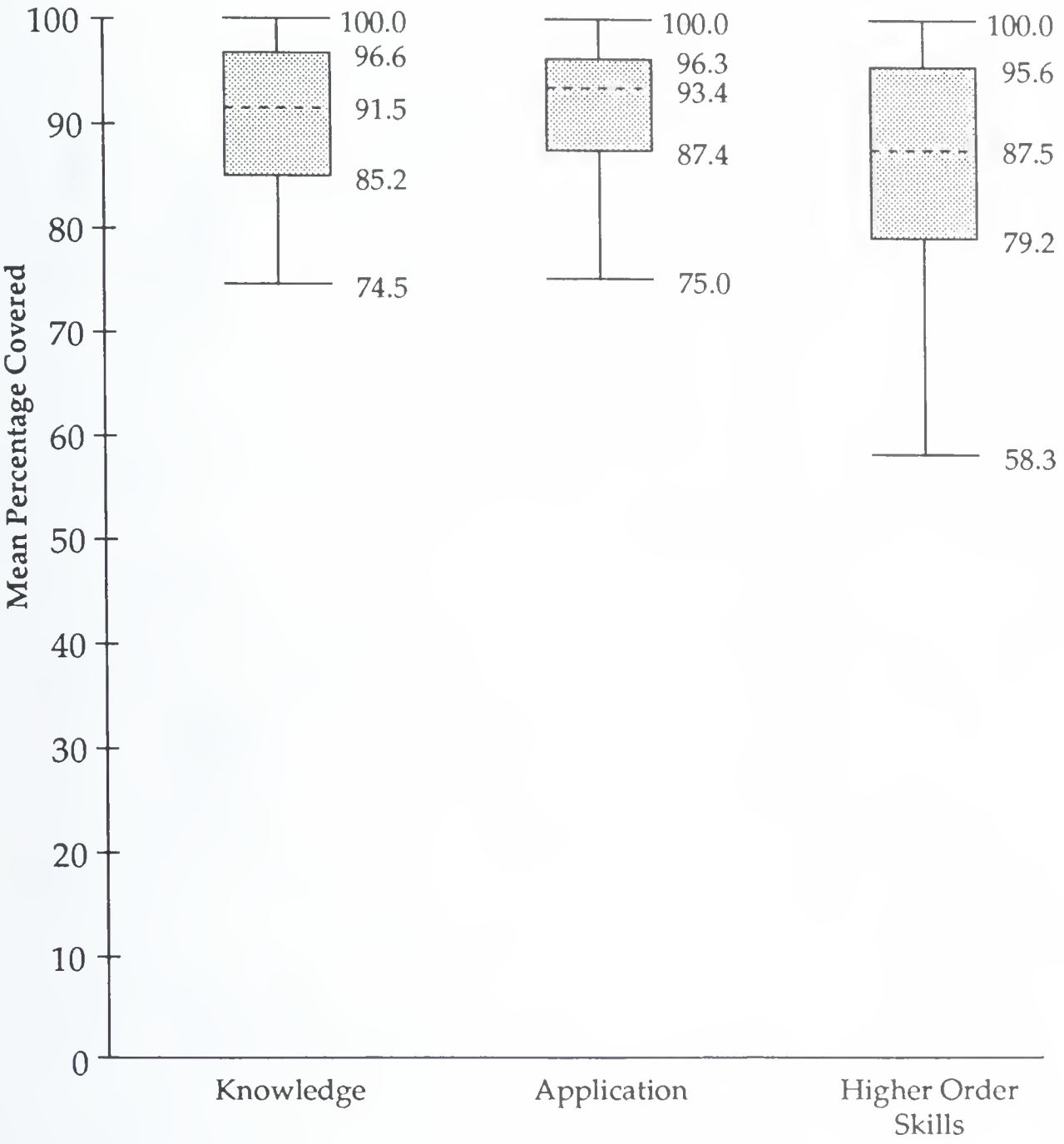
Chemical Reactions -Qualitative Process Level	*Item No.*	*Response Categories (Percentage of Teacher Responses)*				
		Taught or Reviewed	*Taught Prior*	*Taught Later*	*Not in Curriculum*	*Not Taught-Other Reasons*
Knowledge	19	86	2	8	0	4
	50	71	2	10	6	11
	66	100	0	0	0	0
	78	97	1	0	0	1
	100	100	0	0	0	0
	108	57	1	22	10	11
	127	100	0	0	0	0
Application	4	99	1	0	0	1
	9	97	0	1	1	1
	20	98	0	0	0	1
	32	75	0	7	8	11
	41	100	0	0	0	0
	65	99	0	0	0	1
	80	92	1	4	0	2
	103	69	2	12	4	12
	104	99	0	0	0	0
Higher Order Skills	3	85	1	7	1	6
	43	97	0	0	1	1
	68	78	1	5	2	14
	99	99	0	1	0	0
	136	98	0	1	0	1
	137	61	17	4	8	10

Display 23 (continued)
Percentage of Teachers Indicating Whether the Science Necessary to Answer Each Question Had Been Taught or Reviewed and if Not, the Reason for Not Teaching or Reviewing the Science
Provincial Results - Chemistry

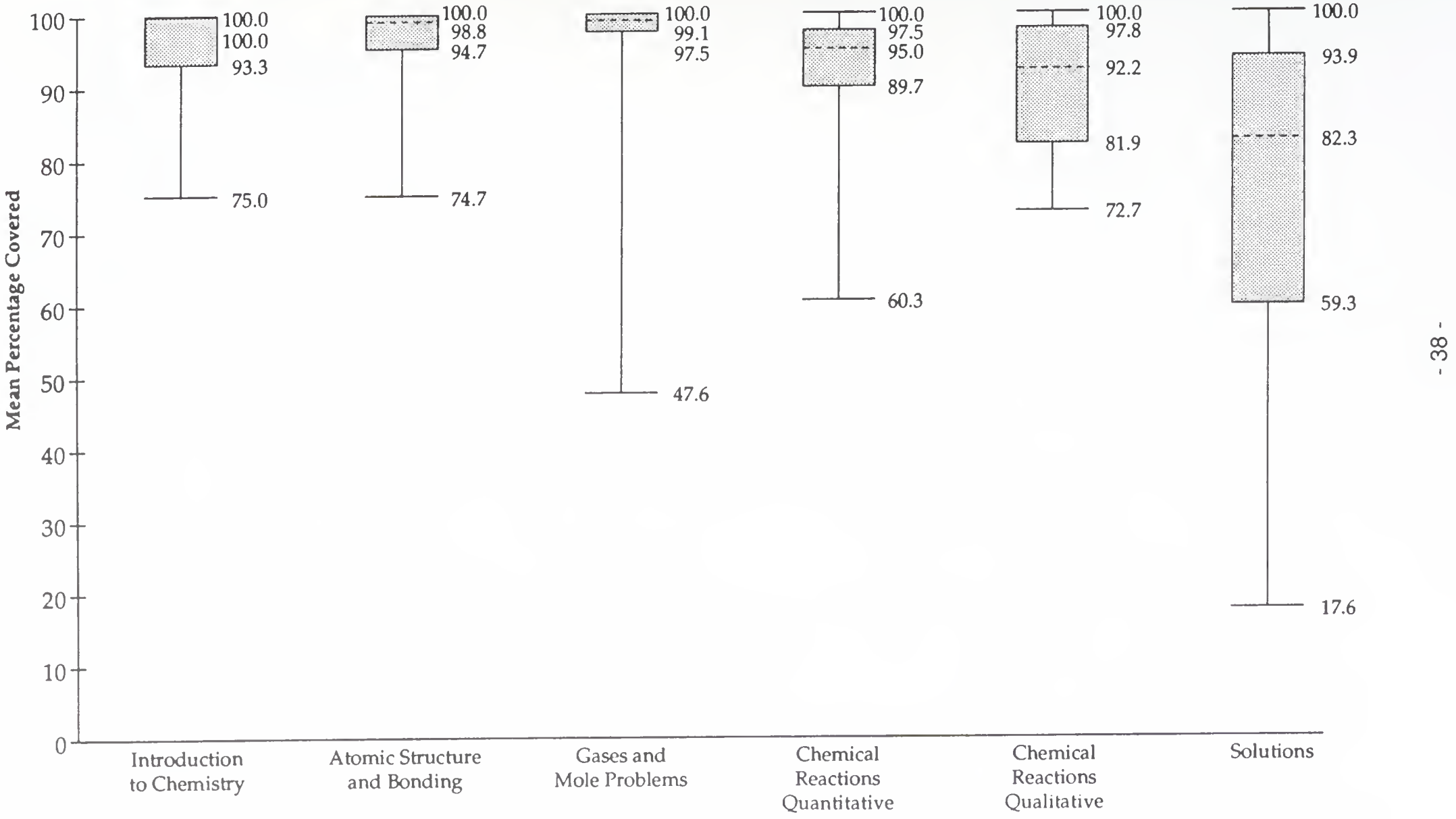
Solutions		*Response Categories (Percentage of Teacher Responses)*				
Process Level	*Item No.*	*Taught or Reviewed*	*Taught Prior*	*Taught Later*	*Not in Curriculum*	*Not Taught-Other Reasons*
Knowledge	33	68	0	18	5	9
	70	75	1	15	0	10
	95	83	0	10	0	8
	139	48	1	28	11	13
	141	84	0	8	0	8
Application	6	84	0	9	0	7
	16	92	0	5	1	2
	21	72	2	13	2	11
	39	50	0	31	8	11
	40	79	0	14	1	6
	71	79	0	11	1	9
	73	85	0	9	0	6
	101	41	0	38	10	10
	110	78	0	12	1	10
Higher Order Skills	47	70	0	18	1	11
	76	72	0	13	4	11
	111	84	0	7	1	8

Display 24

Variation Among Schools in Average Student Opportunity-to-Learn: Questions Grouped by Process Level



Display 25
Variation Among Schools in Average Student Opportunity-to-Learn: Questions Grouped by Content Domain



8.4 TEACHERS' USE OF TEACHING RESOURCES

Teachers indicated the frequency of use of various teaching resources. A wide range was specified including textbooks and reference books, guest speakers, computers, OAIP materials and locally produced equipment and teaching materials. The percentage of teachers in the provincial sample indicating frequency of use of these resources is presented in **Display 26**.

Display 26
Percentage of Teachers Reporting Varying Frequency of Use of Teaching Resources
Provincial Results - Chemistry

Teaching Resources	*Frequency of Use*			
	Not At All	*Occas-ionally*	*Frequ-ently*	*Always*
Textbooks and Reference Books	2	16	51	32
Library Books, Journals, and Magazines	12	76	11	2
Workbooks	63	20	12	5
Laboratory Worksheets	5	26	54	15
Science-Related Computer Software	65	31	3	1
Videotapes, Audiotapes, TVO	15	68	16	1
Field Trips	64	34	1	2
Guest Speakers	65	34	1	0
Films, Slides, and Filmstrips	12	69	18	1
Blackboards, Overhead Projectuals	2	8	43	48
OAIP Materials	20	50	25	5
Commercially Produced Science Apparatus/Equipment	5	33	47	14
Locally Produced Science Apparatus/Equipment	28	58	13	2
Locally Produced Teaching Materials	18	45	31	5

The data shows a fairly traditional use of resources, with frequent use of such resources as texts and references, laboratory worksheets, chalkboards and overhead projectors, and commercially produced apparatus and equipment. Teachers reported only infrequent use of library materials and journals, computer software, and OAIP materials. Field trips and guest speakers were rarely used.

8.5 INSTRUCTIONAL APPROACHES

Ten general approaches to classroom instruction were presented and teachers were asked to indicate their frequency of use of each. These approaches are well known among science educators and are presented in **Display 27**. The socratic

Display 27
Percentage of Teachers Reporting Varying Frequency of Use of Teaching Approaches
Provincial Results - Chemistry

Instructional Approach	*Frequency of Use*			
	Not At All	*Occas-ionally*	*Frequ-ently*	*Always*
Class Instruction	2	27	65	6
Group Instruction	16	62	22	0
Individualized Instruction	47	46	6	1
Textbook	10	62	25	3
Socratic	1	23	64	12
Demonstration	2	63	34	1
Guided Discovery	19	55	26	1
Laboratory	0	14	76	10
Project	28	62	9	2
Science Kit	76	24	0	0

Display 28
Percentage of Teachers Reporting Varying Frequency of Evaluation for Diagnostic, Formative, and Summative Purposes
Provincial Results - Chemistry

Evaluation Purpose	*Frequency of Use*			
	Not At All	*Occas-ionally*	*Frequ-ently*	*Always*
Diagnostic	20	52	22	6
Formative	6	42	46	6
Summative	0	3	45	53

method remains the most frequent approach, along with the use of the laboratory. Group instruction, individualized instruction, guided discovery, and projects are only occasionally used.

8.6 TEACHERS, STUDENTS AND EVALUATION

A series of questions were asked of teachers to determine their purposes in evaluating students, their approaches towards evaluation, and their use of various evaluation methods.

Evaluation can be undertaken for three main purposes. **Diagnostic** evaluation is undertaken to identify an individual student's strengths and weaknesses and identify appropriate remedial measures. **Formative** evaluation serves to modify ongoing instruction and identify areas of class weakness for subsequent presentation of material. **Summative** evaluation serves to identify end-of-unit or end-of-course achievement levels. **Display 28** presents teachers' reports of their frequency of use of each of these three purposes of evaluation.

Summative evaluation is by far the most frequent purpose of evaluation, with diagnostic the least. Implementation of the new guideline with its prescription for a more varied approach to evaluation, is expected to change these results.

Four different approaches to evaluation can be identified. While these approaches share some obvious relationship to the purposes of evaluation, there is some value in examining them independently. **Norm-reference** approaches to evaluation attempt to identify levels of performance by spreading students out and using comparative criteria in assigning marks or grades.

Criterion-referenced approaches are more concerned with identifying areas where instruction has been effective and assessing areas of student weakness.

Individualized-ability approaches to evaluation assign marks or grades through comparison with each student's performance with his or her hypothesized ability in the subject area.

Growth-based approaches focus upon the amount of improvement in performance students

have made rather than their absolute level of performance.

Display 29 shows the approaches that teachers in Ontario report using in their evaluation of students. Criterion-referenced evaluation is clearly the most common approach, with many teachers also reporting the use of individualized ability testing.

Display 30 describes teachers' reports of the actual methods used in the evaluation of students. A wide range of methods was suggested. The most common methods mentioned are traditional tests, examinations, quizzes and laboratory reports. The use of OAIP items is low, with only 30% reporting frequent use. Few teachers report using methods such as reports, projects, oral presentations, and major assignments. About half of the teachers report testing laboratory skills, but very little use is made of evaluation in the affective domain.

A final summary of the approaches teachers use towards evaluation of students is presented in **Display 31**. In this graph is the average of the relative weights assigned to various broad evaluation categories for awarding students' final grades. The four broad categories were tests, examinations, observation (lab techniques, participation), and product analysis (notebooks, reports, projects). This data shows once more the preponderance of use of tests and examinations for evaluation purposes.

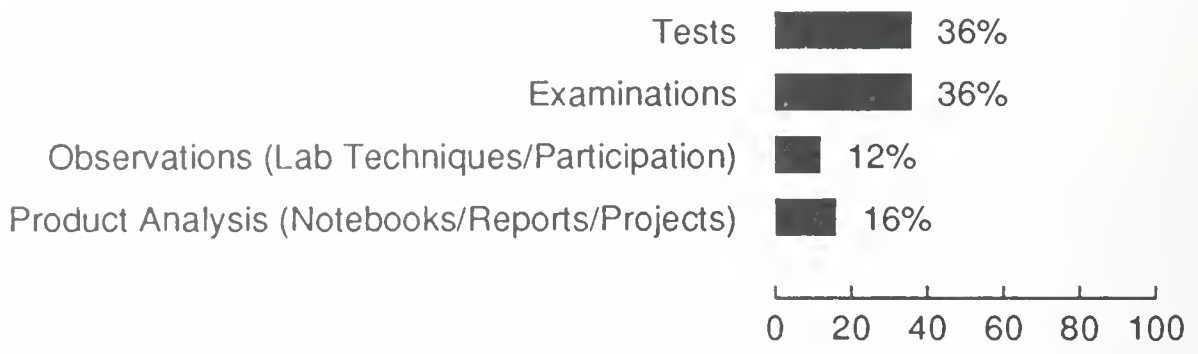
Display 29
Percentage of Teachers Reporting Varying Emphasis Upon Norm-Referenced, Criterion-Referenced, Individualized Ability, and Growth-Based Approaches to Evaluation
Provincial Results - Chemistry

	Emphasis Placed on Approach			
Evaluation Approach	*None*	*Some*	*Moderate*	*Strong*
Norm-Referenced	24	47	22	8
Criterion-Referenced	2	11	45	42
Individualized Ability	16	37	34	13
Growth-Based	39	40	15	6

Display 30
Percentage of Teachers Reporting Varying Frequency of Use of Various Evaluation Methods
Provincial Results - Chemistry

Evaluation Methods	*Frequency of Use*			
	Not At All	*Occas-ionally*	*Frequ-ently*	*Always*
Homework	6	55	33	7
Anecdotal Records	48	46	5	1
Performance of Lab Skills	5	49	40	6
Lab Writeups	1	19	64	17
Science Notes	50	39	8	2
Problem Worksheets	9	45	39	7
Oral Presentations	50	44	5	1
Oral Tests	81	18	1	1
Quizzes (based on one lesson or topic)	5	47	37	10
Tests (based on one unit)	0	3	42	55
Examinations (based on more than one unit)	1	23	19	58
Individual Contracts	81	18	1	0
Student Interviews	82	16	1	1
Peer Evaluation	70	29	1	1
OAIP Questions	23	47	24	6
Local Standardized Tests	76	18	4	3
Commercial Standardized Tests	75	20	3	1
Reports	22	61	16	2
Projects	26	63	8	3
Major Assignments	20	67	9	3
Behaviours and Attitudes	29	51	15	5
Attendance	43	40	11	7
Participation	22	54	16	9
Other	95	3	0	2

Display 31
Proportional Weights Assigned to Various Evaluation Practices by Teachers for Assigning Students' Final Grades
Provincial Results - Chemistry



8.7 CLASSROOM USE OF CALCULATORS AND COMPUTERS

Display 32 is a brief summary of the amount of use of calculators and computers in the classroom. The frequent use of calculators reflects their role as a common tool for arithmetic calculations. Computers are rarely used in chemistry classrooms, either as a resource for computer aided instruction, or as a laboratory tool.

8.8 TEACHER ASSIGNMENT OF STUDENT HOMEWORK

Display 33 summarizes the amount of homework assigned by teachers of the chemistry course. It might be of some interest to compare these figures with those figures reported by students in Display 10. While 79% of teachers report assigning more than 2 hours of homework each week, only 44% of students report spending more than 2 hours per week on chemistry homework.

8.9 THE TEACHING OF THE EXPERIMENTAL METHOD IN CHEMISTRY COURSES

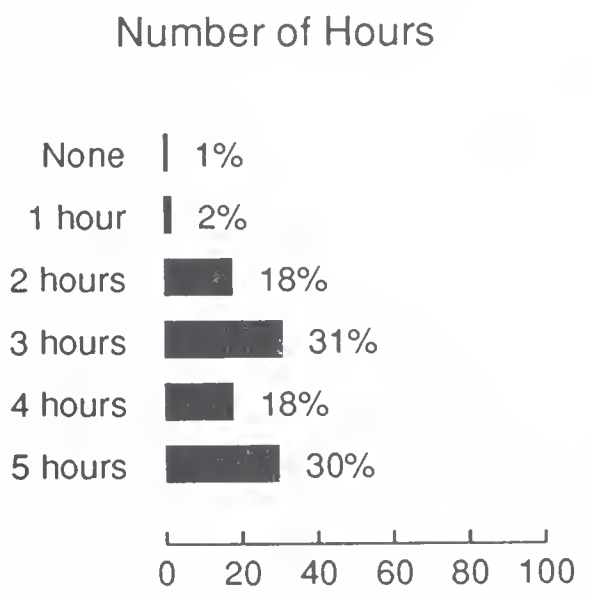
For the purposes of this review, the term **"Experimental Method"** is used to describe a method of asking questions and solving problems that many might refer to as the **"Scientific Method"**. The teaching of the experimental method was seen as a window into the specific instructional and evaluation approaches used to transmit chemistry content and skills. Inquiries were made into the frequency of instruction focussed upon various aspects of the experimental method and the importance placed upon learning objectives associated with the experimental method.

Display 34 presents the frequency of student activities concerned with experimentation. Not surprisingly, students most often carry out traditional experiments, using worksheets or lab manuals. They also often watch teacher demonstrations. Some teachers also give students the opportunity to analyze data not collected by students, such as that collected in a demonstration,

Display 32
Percentage of Teachers Reporting Varying Student Classroom Use of Calculators and Computers
Provincial Results - Chemistry

Level of Student Use	*Calculators*	*Computers*
Not At All	0	61
Rarely	1	30
Occasionally	12	7
Frequently	61	2
Always	26	0

Display 33
Percentage of Teachers Reporting Varying Amounts of Homework Assigned Each Week
Provincial Results - Chemistry



Display 34
Percentage of Teachers Reporting Varying Frequency of Student Activities During the Course Concerned with the Experimental Model
Provincial Results - Chemistry

Student Activities	*Frequency of Activities*			
	Never	*1-3 Times*	*4-8 Times*	*> 8 Times*
Observe the Teacher Doing an Experiment	5	41	39	16
Carry Out an Experiment Using a Worksheet Lab Manual that Gives Specific Purpose, Apparatus, Method, etc.	2	4	13	80
Design and Carry Out an Experiment on their Own on a Topic Chosen by the Teacher	46	46	5	4
Design and Carry Out an Experiment on their Own on a Topic of their Own Choosing	75	25	0	0
Create a Question or Hypothesis to be Investigated, but NOT Carry Out the Experiment	43	50	6	1
Design an Experiment - Identify Variables to be Measured, Held Constant, etc. - but NOT Carry Out the Experiment	51	44	4	1
Collect Data and Record Data Without Doing the Rest of the Steps in an Experiment	57	36	5	2
Analyze Data - Without Doing the Other Parts of the Experiment	17	60	20	3
Draw Conclusions from Data - Without Doing the Other Parts of the Experiment	17	55	25	4
Make Generalizations from Experimental Results - Without Carrying Out the Whole Experiment	20	58	16	6
Prepare a Report Based on the Results of an Experiment Done by the Teacher or Others	46	38	10	6

or from a text or other resource. Few opportunities are given for independent experimental design by students.

Display 35 displays the frequency of instruction focussed upon aspects of the experimental method. Most teachers teach at least some specific lessons focussed on the improvement of students' skills in this area. Less attention seems to be paid to the areas of hypothesis generation or on experimental design, than on dealing with data, conclusions and report writing.

Display 36 describes the importance placed upon learning objectives concerned with the experimental method. Teachers place a great deal of importance on students' learning to analyze data. Many teachers also place great importance on students learning the process for application to other aspects of life. It is encouraging to note that more teachers feel that experiments should be used to discover laws and principles rather than to verify them. The importance placed on demonstrating practical applications is consistent with the spirit of the new guideline.

8.10 BOYLE'S LAW - TEACHING AND EVALUATION

To gather specific information on how teachers instruct and evaluate the learning of specific chemistry laws and concepts, Boyle's Law was chosen as an illustrative chemistry topic.

The possible strategies that could be used to teach and evaluate student learning of Boyle's Law were presented to teachers.

Display 35
Percentage of Teachers Reporting Varying Frequency of Instruction Focussed Upon Components of the Experimental Method
Provincial Results - Chemistry

Components of Experimental Method	*Frequency of Instruction*			
	Never	*1-3 Times*	*4-8 Times*	*> 8 Times*
State Hypotheses or Ask Questions in a More Scientific Way	16	60	14	11
Design Experiments - Identify Variables and Plan Procedures to Collect Data	21	54	18	7
Collect Reliable, Relevant Data	4	42	26	28
Analyze Data	5	33	32	30
Draw Conclusions	6	30	31	34
Make Generalizations	7	35	33	25
Write Reports	4	42	22	31

Display 37 presents data on teachers' use of various teaching strategies for this law. A combination of strategies were employed; the most frequent involved students deriving the law from an experiment that the students have carried out themselves. The use of problem-based exercises was also common.

Display 38 shows the strategies teachers used for assessing student understanding of the law. Most of the evaluation methods listed were used by most teachers. The exception to this is the idea of distinguishing between examples and non-examples of the law.

9. COMPUTERS IN THE CLASSROOM

This section reports upon availability and use of computer hardware and software in the school and in the chemistry classroom.

Teachers responded to several questions concerning computers.

Display 36
Percentage of Teachers Placing Varying Levels of Importance Upon Various Learning Objectives Concerned with the Experimental Method
Provincial Results - Chemistry

Objectives of the Experimental Method	*Level of Importance*		
	None	*Some*	*Great*
Discover Laws and Principles Before Being Taught by Teacher	3	39	58
Verify Laws and Principles After Being Taught by Teacher	5	57	38
Provide Opportunities for Discussions of the Role of Science in Society	7	57	36
Demonstrate Technological Processes	14	68	18
Demonstrate Practical Applications	4	54	42
Learn to Analyze Data	1	18	81
Learn the Process of Experimentation for Application to Other Aspects of Life	4	34	62
Other	90	2	8

Display 39 presents teacher reports of the degree of student access to computers in the school and classroom while **Display 40** shows the different uses that teachers make of computer programs in the classroom.

While 93% of teachers report student access to computers at school, only 21% report student access to computers in the classroom. This does not reflect the intensive use of computers in actual chemical laboratories in the world of work. Of those few teachers who report use in the classroom, the use of tool-type software (spreadsheets, data bases, and word processors) is very low.

The Ministry of Education provides a number of software programs for instructional use through the Ontario Educational Software Service (OESS). Inquiry was made of teachers concerning the availability and use of these programs. **Display 41** presents these results. The availability of these programs in the schools appears to be very low. Even if available, few teachers tend to use them.

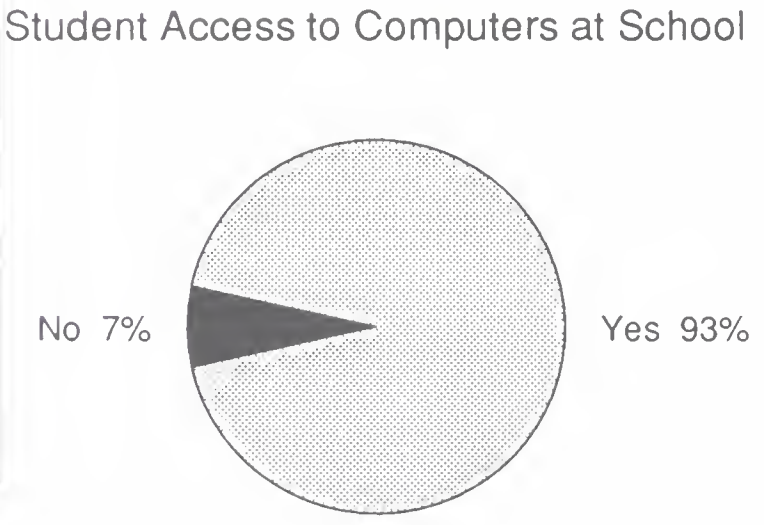
Display 37
Percentage of Teachers Reporting Use of Various Strategies for Teaching Boyle's Law
Provincial Results - Chemistry

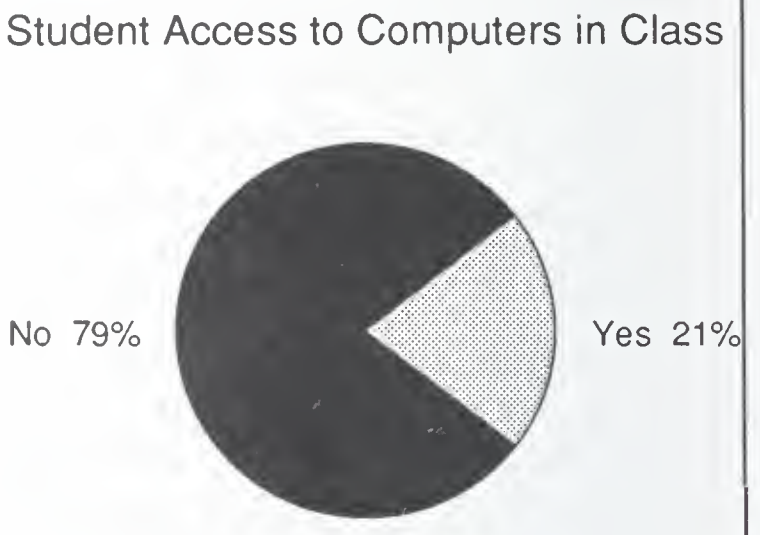
Teaching Strategies for Scientific Law	*Reporting Use*	
	Yes	*No*
State the Law and Have Students Do Related Problems	58	42
State the Law and Have Students Do An Experiment to Verify it	36	64
Have Students Read Textual Material and Do Related Exercises	52	48
Have Students Read Textual Material and Do An Experiment	32	68
Have Students Do An Experiment and Derive the Law from the Results	84	16
Have Students See a Film or Video and Do Realted Exercises	26	74
Have Students See a Film or Video and Do An Experiment	14	86
Other	15	85

Display 38
Percentage of Teachers Reporting Use of Various Evaluation Techniques for Assessing Students' Learning of Boyle's Law
Provincial Results - Chemistry

Evaluation Technique	*Reporting Use*	
	Yes	*No*
Ask Students to Define the Law	81	19
Ask Students to Give Examples of the Law	80	20
Ask Students to Distinguish Between Examples and Non-Examples of the Law	45	55
Ask Students to Describe Applications of the Law	84	16
Ask Students to Solve Problems Using the Law	100	0
Other	7	94

Display 39
Percentage of Teachers Reporting Student Access to Computers in the School and in the Classroom
Provincial Results - Chemistry





Display 40
Percentage of Teachers Reporting Varying Use of Computer Programs in the Classroom
Provincial Results - Chemistry

Various Uses of Computer Programs	*Used*		*Frequency of Use*		
	Yes	*No*	*Rarely*	*Some-times*	*Often*
Spreadsheets	2	98	20	80	0
Wordprocessing	6	94	44	50	6
Database	4	97	60	40	0
OESS Programs (Ontario Educational Software Service)	12	88	52	35	13
Commercial Software Programs	15	85	41	52	8

Display 41
Percentage of Teachers Reporting The Availability and Amount of Use of Various Ontario Educational Software Service Programs
Provincial Results - Chemistry

Ontario Educational Software Service Programs	*Availability*		*Amount of Use*			
	Yes	*No*	*None*	*Rarely*	*Some-times*	*Often*
Logic Gates	11	89	100	0	0	0
Logic Lab	10	90	100	0	0	0
Ideal Gas Simulation	21	79	89	7	4	0
Let There Be Light	7	93	100	0	0	0
Watfile Plus	12	88	99	1	1	0
Electric Chemistry Building	30	71	87	8	3	1
Flamelife	13	87	97	1	1	0

Display 42 shows the percentage of teachers in the provincial sample who have received training in the instructional use of computers and if so, the average number of hours of training received in various settings. The most common method is self-teaching, or a form of coaching by colleagues. In all cases, very few hours of instruction are reported. The results of this limited training of teachers is clearly reflected in the level of student use.

Finally, teachers were asked the following question: "What percent of chemistry classroom time do you feel computer programs could be effectively used, if the proper software were available?" **Display 43** describes the range seen among teachers in the province to this question.

10. THE ATTAINED CURRICULUM

10.1 STUDENT ACHIEVEMENT

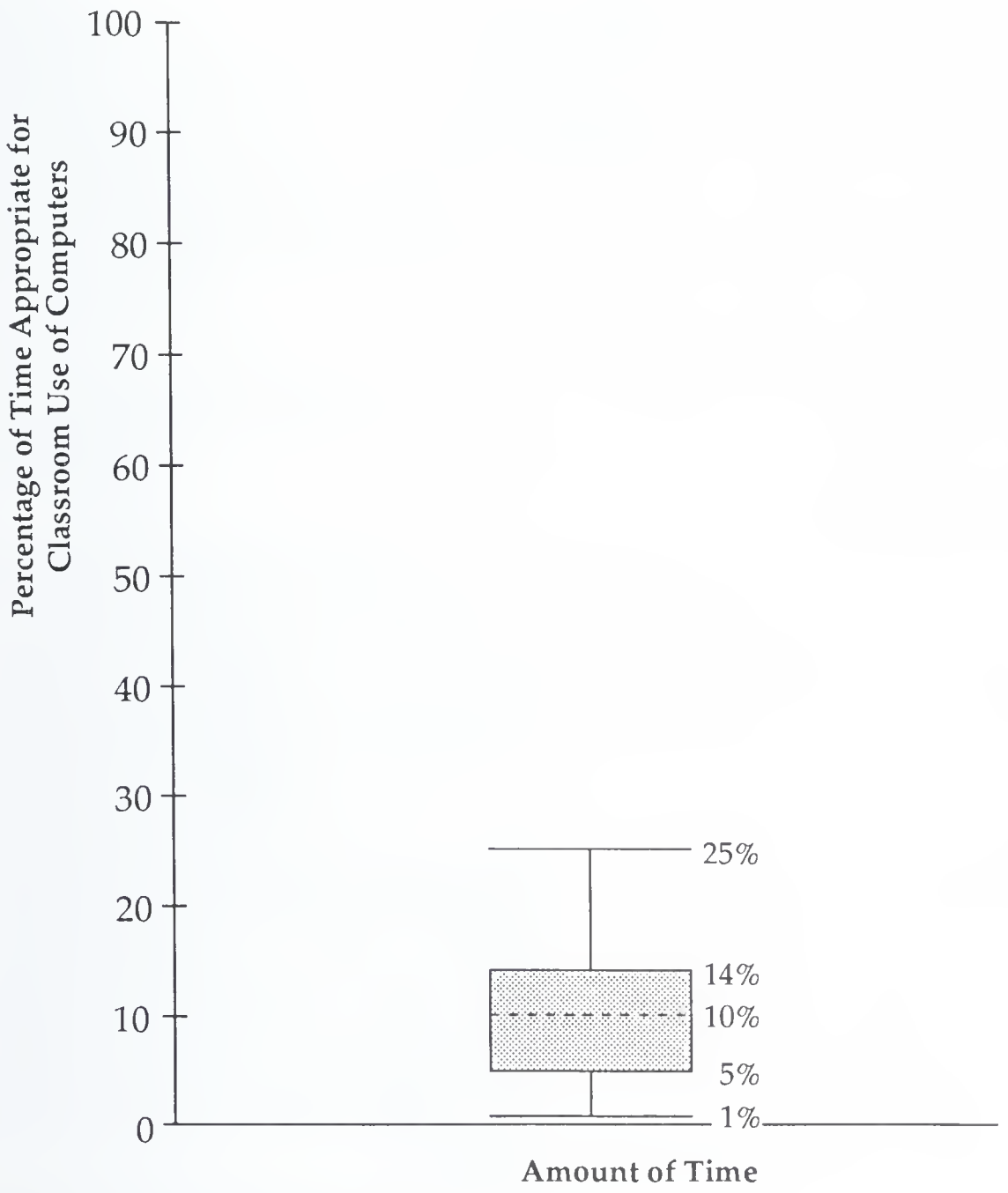
Student achievement was assessed by means of 110 selected-response questions and five extended-response questions selected by a team of Ontario chemistry educators. The questions were placed in five different booklets, each containing 22 selected-response questions and one extended-

Display 42
Percentage of Teachers Reporting Various Sources Of Their Training in Instructional Use of Computers and Hours Received in Such Training
Provincial Results - Chemistry

Training Source	*Training Received*		*Average Number of Hours*
	Yes	*No*	
School-Based (e.g. other teachers)	30	70	2.2
Board-Based (e.g. special course)	18	82	2.0
Commercial Training	2	98	0.2
Professionally-Based (e.g. previous employment)	3	97	0.4
University-Based (e.g. Faculty of Education, OISE)	22	79	4.6
Self-Taught	33	67	2.8
Other	4	97	0.4

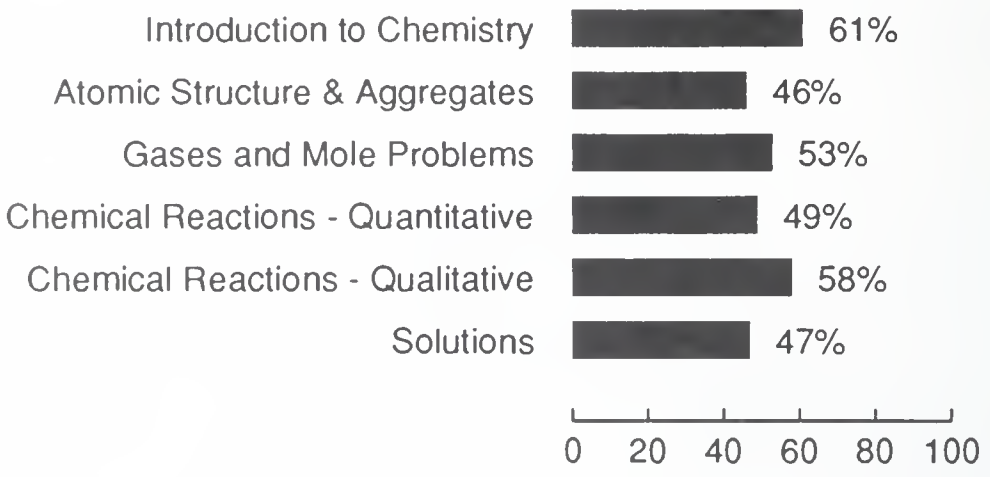
Display 43

Reports of the Percentage of Time That Would Be Appropriate for Classroom Use of Computers if the Appropriate Software was Available



Display 44
Percentage of Students Answering the Questions Correctly
by Process Level
Provincial Results - Chemistry

Display 45
Percentage of Students Answering the Questions Correctly
by Content Domain
Provincial Results - Chemistry



response question. Each student responded to only one booklet. All of the questions were related to the six content domain areas selected for the Review and were also classified as to process level (knowledge, application, or higher-order skills). Each booklet contained a mixture of questions from the content domain and process levels.

The results are presented in a format similar to that used for the student opportunity-to-learn results. Three graphs provide summary data on student achievement, followed by a table presenting student results question by question. These results, both graphic and tabular, also are presented in school and board reports with the appropriate level of data.

10.2 Selected Response Questions

Display 44 shows the percentage of students who answered the questions correctly by process level. This graph provides an overall summary and paints a broad brush stroke of levels of student achievement. The bar for Knowledge presents the average percentage of students answering correctly the 10 questions which were seen as requiring chemistry knowledge. The bar for Application does the same for the 56 questions requiring application skills. The bar for Higher-Order questions presents the average percentage of students correct for the 24 questions requiring these skills. While achievement is not high in any category, it is higher for the simpler Knowledge questions than for the more complex requiring application of knowledge or multi-step problem solving.

Display 45 presents the mean percentage of students correctly answering the questions found in each content domain.

The results in Display 45 show students having more success with the two areas involving Introduction to Chemistry, and Chemical Reactions-Qualitative. Both of these domains involve more descriptive chemistry that is taught with hands-on approaches, than do domains such as Atomic Structure, which emphasizes highly theoretical ideas, and Chemical Reactions Quantitative, which emphasizes calculations. Achievement in the Solutions domain could be related to lower OTL statistics (see Display 21).

Display 46 presents similar results but in this case, questions were grouped by both process level lower (Knowledge) and higher (Application and Higher-Order) skills and content domain. The first set of bars in Display 46 represent the percentage of students answering the Introduction to Chemistry questions grouped by lower and higher process level.

Displays 47 and 48 provide information concerning the range among schools in student achievement in the province. See page *** for an explanation of box and whisker displays.

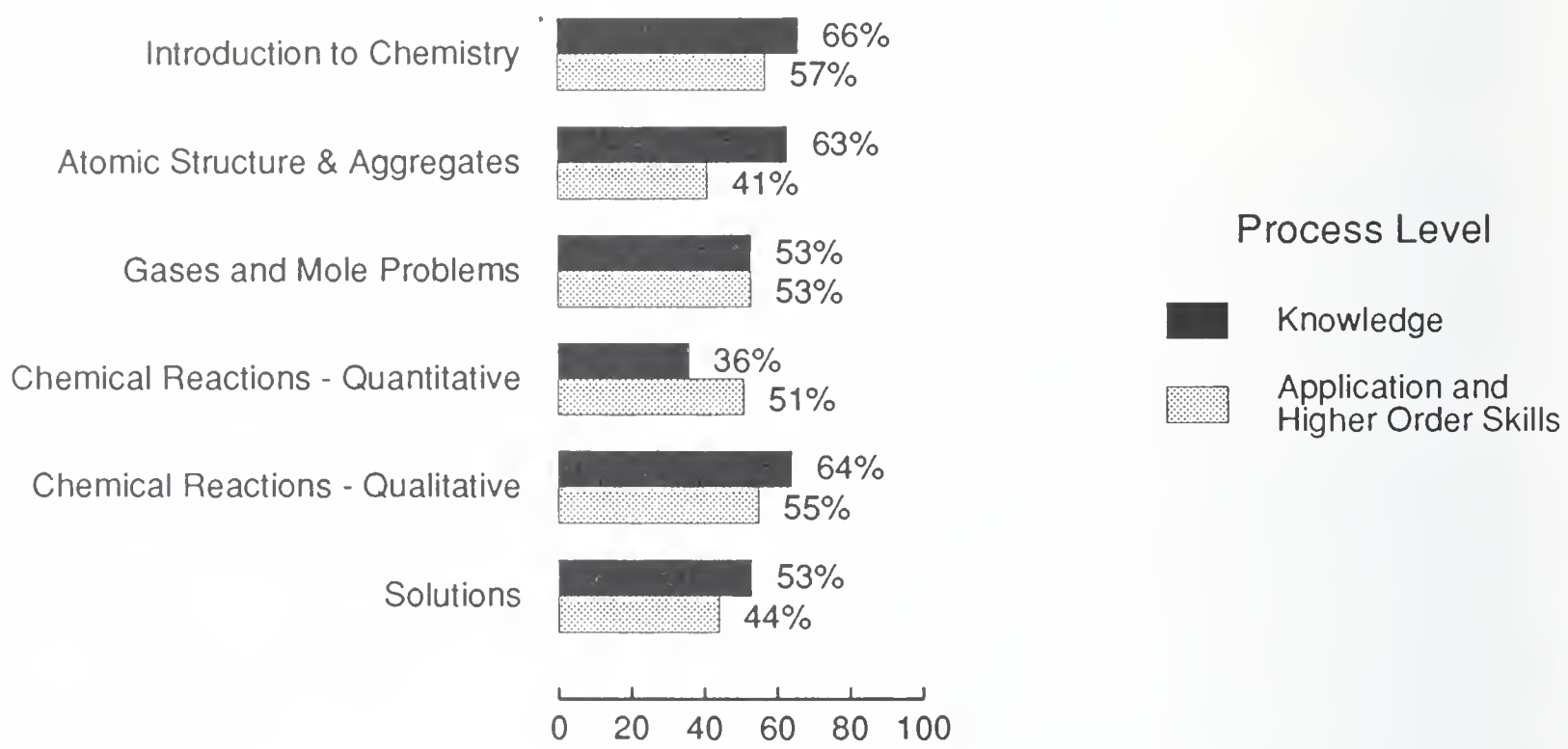
A detailed examination of student achievement results was made by a Provincial Interpretation Panel. The results of their deliberations are found in section 10.1.4. The expectation is that these results will encourage science educators to continue the process of curriculum reform that has begun throughout Ontario and to use these results to guide them.

The previous graphs detailed student achievement for the provincial sample by process level, content domain, and process and content domain. **Display 49** provides achievement information at the individual question level. For example, the ten questions for Introduction to Chemistry have been grouped together and are identified by process level. Questions (from the Student Assessment Booklets) 7, 13, 44, 81, 97 are seen as knowledge questions; questions 46, 63, 109, 121 are identified as application questions; and question 122 is seen as a higher-order skills question. A similar procedure has been used for the questions in the other content domain areas.

For each question, the following is provided:

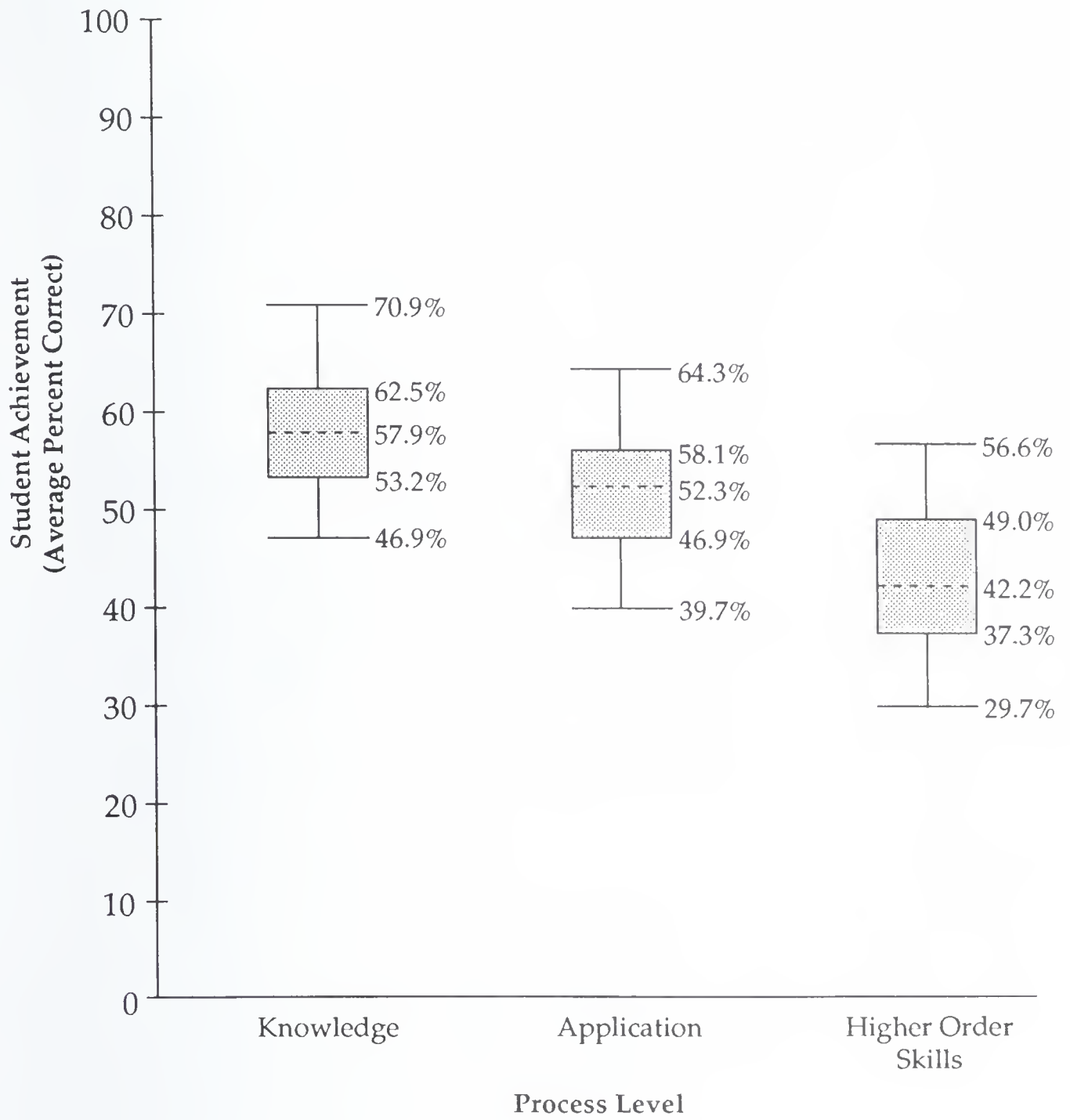
- the percent correct predicted by teachers; (In the majority of cases, teachers predicted student achievement with considerable accuracy);
- the answer key;
- the distribution of student choices (by percent); Careful analysis of student response patterns can assist in closely identifying specific difficulties encountered by the students;
- the total number of responses.

Display 46
Percentage of Students Answering the Questions Correctly by Process Level and Content Domain
Provincial Results - Chemistry



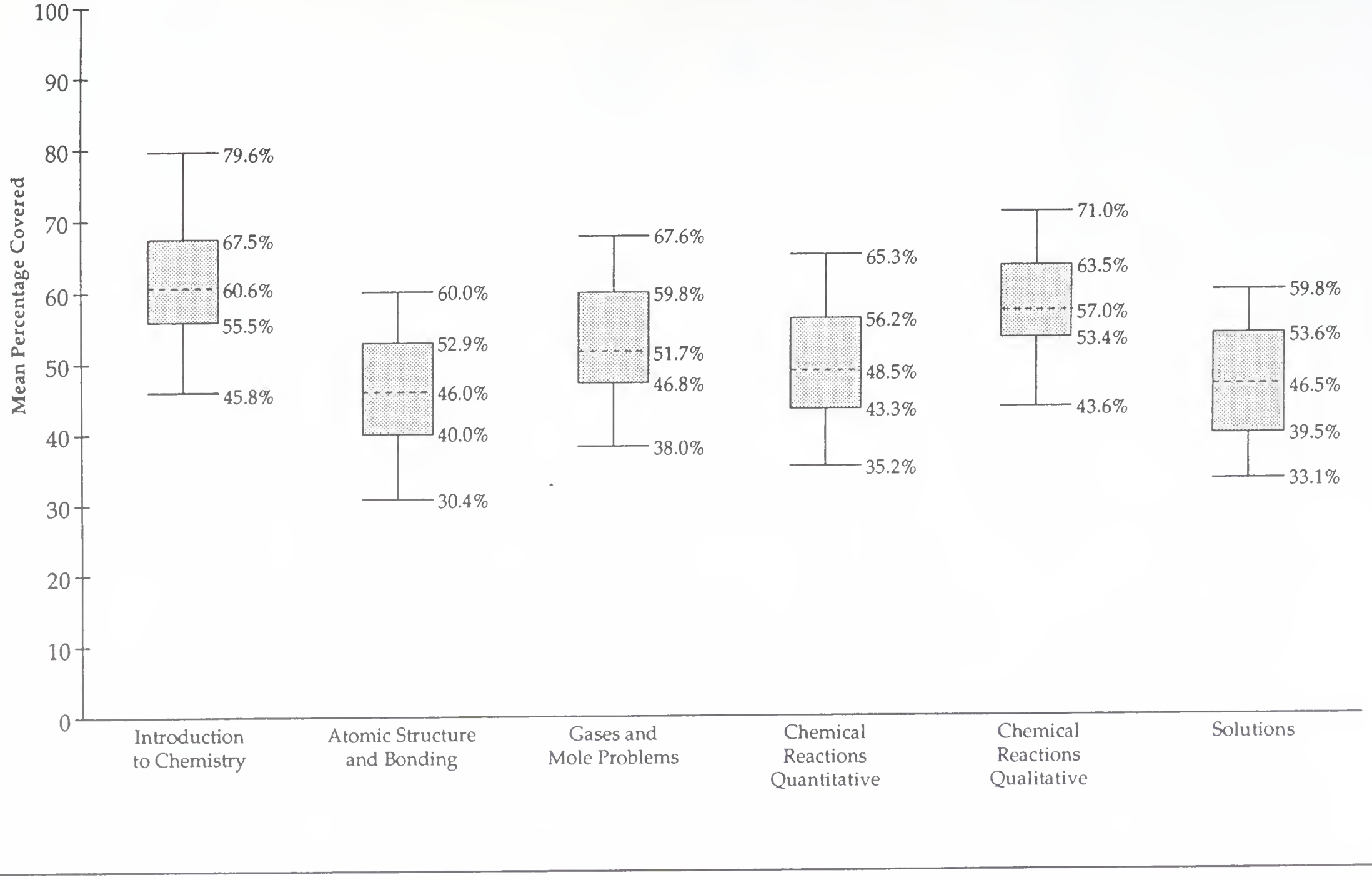
Display 47

Variation Among Schools in Average Student Achievement: Questions Grouped by Process Level



Display 48

Variation Among Schools in Average Student Achievement: Questions Grouped by Content Domain



Display 49
Detailed Item Analysis for Student Achievement Questions
Provincial Results - Chemistry

Introduction to Chemistry *Process Level*	*Item No.*	*Teacher Predicted Correct (%)*	*Key*	*Student Choices (%)* *A*	*B*	*C*	*D*	*Omits*
Knowledge	7	53	A	51	11	19	18	1
	13	65	C	20	6	55	18	0
	44	61	C	7	7	64	19	2
	81	87	D	3	4	3	88	1
	97	73	B	13	69	11	6	0
Application	46	70	B	6	77	10	5	2
	63	54	B	13	41	19	26	1
	109	73	A	81	7	6	6	1
	121	49	A	44	10	25	21	0
Higher Order Skills	122	52	D	8	36	14	41	1

Display 49 (continued)
Detailed Item Analysis for Student Achievement Questions
Provincial Results - Chemistry

Atomic Structure and Aggregates *Process Level*	*Item No.*	*Teacher Predicted Correct (%)*	*Key*	*Student Choices (%)* *A*	*B*	*C*	*D*	*Omits*
Knowledge	1	79	B	6	61	23	9	0
	42	78	B	12	75	12	1	1
	67	84	B	2	80	3	14	0
	98	66	A	63	26	8	2	1
	126	61	A	36	29	6	29	0
Application	5	65	B	13	58	10	18	1
	22	65	C	16	10	64	8	2
	34	57	C	22	17	49	11	0
	36	69	B	6	34	24	35	1
	62	59	B	19	36	23	20	1
	79	58	D	27	39	9	24	1
	96	56	C	33	10	35	20	1
	106	57	B	14	44	24	14	4
	123	68	C	15	9	56	20	1
	125	45	C	38	25	12	25	1
	128	58	B	34	53	10	3	0
Higher Order Skills	8	51	B	29	34	9	27	1
	69	56	B	23	39	23	14	1
	82	40	A	25	22	33	14	5
	124	58	B	16	49	6	28	0

Display 49 (continued)
Detailed Item Analysis for Student Achievement Questions
Provincial Results - Chemistry

Gases and Mole Problems Process Level	Item No.	Teacher Predicted Correct (%)	Key	Student Choices (%) A	B	C	D	Omits
Knowledge	12	60	D	21	14	25	39	1
	38	68	D	1	6	34	58	1
	74	66	B	4	39	26	29	2
	105	66	C	8	19	61	10	2
	134	78	D	31	3	2	63	1
	135	75	D	7	27	8	57	1
Application	2	74	D	9	33	4	54	0
	15	57	C	35	4	49	11	1
	35	54	D	9	21	12	57	1
	37	62	C	14	6	72	5	2
	72	63	B	11	44	7	37	2
	93	59	B	9	74	11	4	1
	102	53	B	34	44	12	7	2
	107	54	B	10	42	36	10	3
	129	70	B	5	66	9	20	0
	142	63	B	10	33	42	12	4
Higher Order Skills	14	60	B	26	45	14	14	2
	31	60	D	11	15	24	47	3
	75	59	C	8	16	63	10	3
	112	58	B	11	48	15	22	4
	138	50	D	22	4	19	54	1

Display 49 (continued)
Detailed Item Analysis for Student Achievement Questions
Provincial Results - Chemistry

Chemical Reactions - Quantitative Process Level	*Item No.*	*Teacher Predicted Correct (%)*	*Key*	*Student Choices (%)*				
				A	*B*	*C*	*D*	*Omits*
Knowledge	10	64	B	30	39	9	22	0
	45	51	C	43	17	33	6	1
Application	11	58	A	43	9	27	20	1
	18	71	C	13	9	61	16	1
	48	65	D	17	31	14	37	1
	49	60	B	18	50	10	19	2
	51	58	B	20	43	14	20	3
	61	82	D	3	10	4	82	0
	77	73	C	6	9	80	3	1
	92	51	C	14	19	55	8	4
	94	58	B	21	50	14	9	6
	130	63	D	10	20	14	55	1
	132	68	A	60	12	13	14	1
	133	62	A	50	5	36	7	1
	140	57	A	48	15	23	10	3
Higher Order Skills	17	64	C	6	10	78	4	1
	52	41	C	26	18	35	18	4
	64	32	C	29	50	15	2	2
	91	48	A	53	23	15	4	5
	131	40	D	5	21	52	17	3

Display 49 (continued)
Detailed Item Analysis for Student Achievement Questions
Provincial Results - Chemistry

Chemical Reactions - Qualitative Process Level	*Item No.*	*Teacher Predicted Correct (%)*	*Key*	*Student Choices (%)*				
				A	*B*	*C*	*D*	*Omits*
Knowledge	19	52	B	18	39	19	23	1
	50	47	D	15	8	27	48	2
	66	88	D	1	2	3	94	0
	78	77	A	90	4	4	1	1
	100	80	D	4	9	7	79	1
	108	35	C	22	17	33	25	4
	127	70	C	9	23	64	3	1
Application	4	73	B	4	84	6	5	0
	9	63	A	74	4	11	10	1
	20	58	C	7	10	55	26	1
	32	45	A	42	18	16	23	1
	41	83	A	63	8	22	6	1
	65	75	B	10	78	8	3	1
	80	56	B	21	51	16	9	3
	103	46	D	21	26	8	44	1
	104	71	D	13	19	12	54	1
Higher Order Skills	3	47	C	38	27	28	5	2
	43	46	B	9	63	18	8	3
	68	33	A	50	24	15	8	3
	99	60	B	12	44	6	37	1
	136	55	D	21	19	11	47	2
	137	43	A	49	17	18	13	2

Display 49 (continued)
Detailed Item Analysis for Student Achievement Questions
Provincial Results - Chemistry

Solutions		*Teacher Predicted*		*Student Choices (%)*				
Process Level	*Item No.*	*Correct (%)*	*Key*	*A*	*B*	*C*	*D*	*Omits*
Knowledge	33	42	D	4	44	12	39	1
	70	60	C	13	16	69	2	1
	95	59	D	12	18	22	47	2
	139	30	B	9	52	15	22	2
	141	58	D	11	24	7	56	2
Application	6	62	C	11	16	68	4	2
	16	62	A	48	24	10	16	1
	21	46	A	34	48	3	14	1
	39	33	C	26	19	33	20	2
	40	58	D	15	21	10	51	3
	71	51	A	52	10	22	14	2
	73	57	A	51	11	7	29	2
	101	30	C	33	18	33	13	3
	110	46	A	53	15	16	11	5
Higher Order Skills	47	39	B	15	25	15	42	3
	76	43	A	41	8	15	33	2
	111	49	C	11	21	41	21	6

10.3 Extended-response questions.

In addition to the 110 selected-response questions, five additional achievement questions were asked which required responses consisting of a few sentences or paragraphs. Each student answered one of these extended-response questions.

These questions have been analyzed by the Ministry for provincial review schools only. The Ministry has produced *A Guide for the Analysis of Extended Response Questions in the Chemistry Provincial Review* which contains the analysis criteria which was used. School boards have been provided with this guide to analyze student responses from schools which were not part of the provincial sample.

While each of these questions concerned topics common to both guidelines, they tended to deal with course material which is not necessarily confined to a particular content domain. Three of the questions (those in booklets 1, 3, and 4) dealt with laboratory-based problems and required some understanding of laboratory equipment and procedures as well as chemical concepts. Question 2 dealt with a Science in Society issue, Acid Rain. Question 5 required students to comment on the chemical and physical properties of an actual piece of matter. In this case, a piece of Mylar film was attached to each booklet containing the question.

The extended-response questions were designed to indicate student achievement along a number of dimensions, each of which is a part of the Senior Division Advanced Level Chemistry course. For the purposes of analysis, each dimension was then subdivided into a number of different categories.

For the purposes of this analysis, the term **"DIMENSION"** is intended to indicate an aspect of the Senior Division, Advanced Level Chemistry Program. Typical examples include Laboratory Skills, Safety Awareness, Knowledge, and Applications of Laws and Principles. Several of these dimensions are examined in different contexts using different questions.

Each dimension is then subdivided into a numbered **"CATEGORY"** which indicates the level of student achievement in each dimension. It is important to realize that the assignment of a category to a student response is not necessarily an indicator of a "mark" in the traditional sense, but an indication of student achievement in a specific dimension.

An example of this process of analysis can be found in the analysis of question 2 ("Acid Rain"), as found in Display 50(b). An examination of the categories from Dimension A (Knowledge), shows that, while Category 4 clearly represents a higher level of achievement than category 2, but not in a numerical ratio of 4:2. In other words, Category 4 of 5 categories does <u>not</u> imply a "mark" of 4 out of 5. It should also be noted that in some dimensions, a higher category does not necessarily indicate a higher level of achievement (See Question 4, Dimension B, for an example.)

Display 50 (a-e) contains the data on the student achievement for the five extended-response questions.

Booklet One (Qualitative Analysis): This question allowed students to incorporate many ideas from both the theoretical and practical curriculum. The team felt that most students attempted to present an organized response, but that perhaps lack of experience in qualitative analysis, coupled with the number of unknowns (5) may have contributed to student achievement.

Booklet Two (Acid Rain): Students demonstrated a relatively good understanding of the causes and chemical basis of acid rain, perhaps indicative of the increased emphasis on the Science-Technology-Society interface in the new guideline.

Booklet Three (Molar Mass of Gas): This question tested the students' ability to select laboratory techniques from previous experience and to synthesize them into a new procedure. Student achievement in this question indicated weaknesses in understanding the handling of gases in the laboratory. Few students were able to make the connections between mass and volume required to find the molar mass.

Display 50a
Percentage of Student Responses Falling Within Various Response Categories for the Components of the Extended Response Achievement Questions
Provincial Results - Chemistry

Qualitative Analysis

Dimension A: Knowledge of Chemical and Physical Properties of Substances	*(%)*
No response	14
Only irrelevant information	27
Demonstrated limited knowledge of chemical and physical properties	41
Demonstrated appropriate but incomplete knowledge of relevant properties	14
Demonstrated sufficient knowledge of relevant properties	3

Dimension B: Experimental Design - Systematic and Logical Analysis	*(%)*
No response	15
Inconsistent approach i.e. no design apparent	41
Logical but incomplete approach	29
Logical and complete approach (unknowns need not be identified)	15

Dimension C: Number of Successful Identifications	*(%)*
No response	29
Identified one substance correctly	16
Identified two substances correctly	9
Identified three substances correctly	5
Identified four substances correctly	2
Identified five substances correctly	3
Zero correct	35

Dimension D: Safety Considerations	*(%)*
No response	16
The prohibition of the TASTE test was ignored	2
Some steps in the procedure appear to be unsafe	2
Chemicals with known safety hazards are suggested	0
All experimental details appear to be in accordance with conventional safety procedures	79

Display 50b
Student Achievement on Extended Response Question 2
Provincial Results - Chemistry

Acid Rain

Dimension A: Knowledge	*(%)*
No response	7
Inappropriate response (e.g., acid, pollution, incinerator, carbon, carbonic acid...)	16
Response not related to Acid Rain, but the substance is a pollutant (e.g, Chloride, dioxins...)	1
Non-major source of Acid Rain (e.g., carbon dioxide, carbon monoxide, nitrous oxides, sulfides...)	29
Major source of Acid Rain, but named inappropriately (e.g., sulfur emissions, sulfur, sulfuric acid, sulfur oxide, sulfuric oxide ...)	20
Major source of Acid Rain identified (e.g. SO2, SO3)	27

Dimension B: Symbols/Equations	*(%)*
No response	26
Inappropriate response or response not related to part A	15
Some proper formulas used in an equation	27
Correct formulas used, correct equation, not balanced	5
Correct formulas used, correct equations, balanced	27

Dimension C: Knowledge/Awareness	*(%)*
No response	12
Inappropriate response (e.g., burning of paper, burning of salts)	13
A source of pollution, but not for the substances identified in Part A	8
Identified a non-specific source (e.g., industrial parks, factories, Sudbury...)	35
The source is a minor one for the substance identified in Part A	5
A major source - e.g., CO -car exhaust; NOx -car exhaust; SO2 -ore smelters; thermo-generating plants (coal burning)	26

Dimension D: Social/Political Awareness	*(%)*
No response	8
Some response, not appropriate to the selected control or the Acid Rain problem	18
One problem identified	25
One problem identified and explained	36
Two problems identified	3
Two problems identified and explained	9
Three or more problems identified and explained	1

Display 50c
Student Achievement on Extended Response Question 3
Provincial Results - Chemistry

Tablets - Gas

Dimension A: Knowledge and Applications of Laws and Principles	*(%)*
No response	37
Demonstrated a knowledge of how to find the mass of the gas	28
Did not demonstrate a knowledge of how to find the mass of the gas but did indicate some knowledge of gas properties or of relevant measurements	17
Included Category 1 and demonstrated a knowledge of tests for physical or chemical properties of the gas	7
Included Category 3 and knew that the identity of the gas could be used to find its molar mass from reference material	2
Included Category 1 and demonstrated a knowledge of how the volume of the gas could be used to arrive at its molar mass but the method was incomplete or deficient	6
Included Category 1 and knew how to correctly calculate the molar mass of the gas	4

Dimension B: Experimental Design	*(%)*
No response	20
Some response but design not workable	53
Designed an effective method to find the mass of gas	16
Designed a quantitative method fo collecting the gas, but the procedure was deficient e.g., The system was not closed or the method of measuring the volume of the gas was not precise	5
Designed an appropriate quantitative method of measuring the volume of the gas	1
Category 2 and 3	4
Category 2 and 4	1
Designed a workable experiment using other equipment	1

Dimension C: Selection and Use of Equipment	*(%)*
No response	23
Selected some equipment but not appropriate	49
Selected some of the equipment needed	24
Selected all of the equipment needed	4

Dimension D: Measurement	*(%)*
No response	41
Made appropriate measurements to find the mass of the gas	30
Made some of the measurements or tests required to find Molar Mass	25
Made all necessary measurements or tests required to find the Molar Mass of the gas	5

Display 50d
Student Achievement on Extended Response Question 4
Provincial Results - Chemistry

Alloys

Dimension A: Knowledge	*(%)*
No response	35
Some limited knowledge shown of elements	32
Knowledge of relevant properties of elements	1
Knowledge of relevant properties of elements and of the alloy	12
Knowledge of elements not related to intent of the question	20

Dimension B: Laboratory Skills	*(%)*
No response	32
Use of appropriate equipment	2
Use of appropriate materials	0
Use of appropriate equipment and materials	12
All of the above and proper attention to procedural details	2
Inappropriate selection of laboratory equipment and materials and/or limited response	51

Dimension C: Experimental Design	*(%)*
No response	29
Design meaningless or unworkable - from a chemical/physical perspective	34
Design incomplete	15
Design complete but some explanatory steps missing	15
Design complete and workable	5
Design novel or creative (may have suggested reagents/equipment not on list)	1
Design novel or creative but incomplete	2

Dimension D: Measurements/Calculations/Results	*(%)*
No response	44
Use of appropriate measuring devices	10
Data indicated but no calculation(s)	8
Caluclations and measurements inappropriate and/or incomplete	19
Calculations only - but appropriate	4
Measurements and calculations appropriate	14

Dimension E: Safety	*(%)*
No response	37
Introduced reagents or procedures with recognizable safety hazards but with no concern indicated	60
Cursory attention paid to safety concerns	3
Effective attention paid to safety concerns	0

Display 50e
Student Achievement on Extended Response Question 5
Provincial Results - Chemistry

Mylar

Dimension A: Knowledge of Properties of Pure Substances	*(%)*
No response	12
States 2 or more properties of the substance	58
Identifies one property useful in classification of the substance as pure or mixture	5
Correctly describes the substance in terms of the property identified	26

Dimension B: Knowledge of Properties of Metals and Non-Metals	*(%)*
No response	11
Identifies 1 property useful in classification of the substance as metal or non-metal	4
Identifies 2 properties useful in classification	6
Correctly describes the substance in terms of one of the properties identified	30
Correctly describes the substance in terms of both of the properties identified	49

Dimension C: Interpretations - (Pure Substance vs Mixture)	*(%)*
No response	54
Attempts to classify the substance as a pure substance or a mixture	22
Makes a reasonable interpretation of the property already identified to classify the substance as a pure substance or a mixture	25

Dimension D: Interpretations - Metal vs Non-Metal	*(%)*
No response	41
Refers to one of the properties already identified and attempts to use it to classify the substance as metal or non-metal	14
Refers to two of the properties already identified and attempts to use them to classify the substance	5
Makes a reasonable interpretation using one of the properties identified	26
Makes a reasonable interpretation using two properties	15

Dimension E: Experimental Design	*(%)*
No response	14
Identifies properties not mentioned previously, but not useful	14
Identifies one property not mentioned previously, useful in answering (i) or (ii)	11
Identifies properties not mentioned previously, useful in answering (i) and (ii)	2
Provides a test leading to a result useful in (i) or (ii)	26
Provides tests leading to results useful in (i) and (ii)	9
Correctly predicts observations corresponding to 1 test proposed for (i) or (ii)	17
Correctly predicts observations corresponding to tests proposed ofr (i) and (ii)	6

Booklet Four (Alloys): The responses of students to this question indicated a general lack of experience in tackling this type of laboratory problem. While evidence of theoretical knowledge was often present, transference to application was often very limited.

Booklet Five (Mylar Film): Students responded very well to this actual sample of material attached to the sheet. Students were able to list many properties and report them in a well-written manner. Evidence from samples still attached to answer sheets suggested some creative "experimentation". Students had difficulties suggesting experiments to distinguish among the various types of matter.

The general results for questions requiring laboratory-based problem solving indicated a very limited degree of understanding by students, perhaps reflected in the lack of opportunities for similar experiences in their own school laboratories (see Displays 9, 19 26, and 27).

10.4 Interpretation Panel Ratings of Student Achievement

An interpretation panel consisting of members of various educational and public constituencies met to consider the levels of student achievement

Display 51
Interpretation Panel Ratings of Student Achievement
by Content Domain and Process Level
Provincial Results - Chemistry

Content Domain	*Mean % Correct*	*Rating*
Introduction to Chemistry	61	3.3
Atomic Structure and Aggregates	46	2.4
Gases and Mole Problems	53	2.9
Chemical Reactions - Quantitative	49	2.8
Chemical Reactions - Qualitative	58	3.0
Solutions	47	2.2
Process Level	*Mean % Correct*	*Rating*
Knowledge	58	2.8
Application	52	2.8
Higher Order Skills	43	2.5

Display 52
Interpretation Panel Ratings of Student Achievement by Individual Questions Together with Summary Question Data Provincial Results - Chemistry

Introduction to Chemistry	*P Value*	*OTL*	*TPC*	*IPR*
Knowledge				
7. A white solid which has a sharp,...	51	92	53	4
13. A mixture consists of substances...	55	99	65	2
44. The Law of Definite Proportions...	64	96	61	3
81. An example of an element is...	88	100	87	5
97. A pure substance that contains...	69	99	73	3
Application				
46. An Ontario sample of the compound...	77	95	70	5
63. Which of the following diagrams...	41	90	54	2
109. A physical change in a substance...	81	98	73	4
121. An unknown material is added to...	44	96	49	3
Higher Order Skills				
122. You have examined a material and...	41	94	52	2

seen in this provincial review. Members of the panel are named in the appendices. The panel examined student achievement for each question against a background of their professional judgement and their understanding of the student population, curriculum emphases, current classroom practices, the curriculum and public expectations. Interpretation panel ratings are given on a five-point scale:

Superior(5); Strong(4); Satisfactory(3); Marginal(2), or Weak(1)

Display 51 provides their judgments of student achievement in selected-response questions by ontent domain and process level. The numbers given as ratings refer to a weighted average of the numerical values of the ratings assigned by the interpretation panel. A value of 3.3, for example indicated that the panel rated student responses between Satisfactory (3.0) and Strong (4.0).

Display 52 provides ratings of provincial student achievement question by question.

Display 52
Interpretation Panel Ratings of Student Achievement
by Individual Questions Together with Summary Question Data
Provincial Results - Chemistry

Atomic Structure and Aggregates	*P Value*	*OTL*	*TPC*	*IPR*
Knowledge				
1. A bond in which atoms share a pair...	61	98	79	3
42. In the Periodic Table elements...	75	100	78	4
67. An atom becomes a negatively charged...	80	100	84	4
98. The greater the electronegativity...	63	93	66	3
126. The nuclear atom was first proposed...	36	95	61	2
Application				
5. The following is a list of the usual...	58	99	65	3
22. Chemists believe that the chemical...	64	98	65	3
34. Which of the following elements has...	49	94	57	3
36. How many protons, neutrons, and...	34	100	69	2
62. The most highly ionic bonds exist...	36	93	59	2
79. The mass numbers of two naturally...	24	97	58	1
96. Which of the following electron...	35	97	56	2
106. The group of particles having...	44	99	57	3
123. If z represents the atomic number of...	56	100	68	2
125. Sharing of electrons in forming a bond...	12	85	45	1
128. Within a vertical group of elements...	53	93	58	3
Higher Order Skills				
8. The elements neon (Ne), sodium (Na),...	34	93	51	2
69. Consider the species...	39	98	56	2
82. Values of 1st 2nd and 3rd ionization ...	25	70	40	1
124. Consider the electron configurations...	49	95	58	3

Display 52
Interpretation Panel Ratings of Student Achievement
by Individual Questions Together with Summary Question Data
Provincial Results - Chemistry

Gases and Mole Problems	*P Value*	*OTL*	*TPC*	*IPR*
Knowledge				
12. The statement: "the number of molecules...	39	88	60	1
38. Which of the state(s) of matter fit(s)...	58	98	68	3
74. If the pressure is kept constant the...	39	94	66	2
105. Boyle's Law can be expressed by the...	61	93	66	3
134. To change a temperature reading...	63	96	78	3
135. The expression "absolute zero" refers...	57	96	75	2
Application				
2. The mass of oxygen in 3.0 mol of 02 gas...	54	99	74	2
15. Which one of the following statements...	49	96	57	3
35. If 2 containers of different ideal gases...	57	93	54	3
37. At a constant pressure, 20L of a gas...	72	95	62	5
72. 100 mL of an ideal as initially at...	44	95	63	3
93. A sample of O2. (oxygen), at STP has...	74	95	59	5
102. When the pressure on 1.0 L of gas...	44	94	53	3
107. When the pressure exerted on 1 L...	42	93	54	3
129. The number of moles of He (helium)...	66	100	70	3
142. What is the volume of 16 g of O2...	33	93	63	1
Higher Order Skills				
14. 5.00 L of dry oxygen (O2) are collected...	45	93	60	2
31. A 300 mL sample of an ideal gas at...	47	94	60	3
75. A quantity of gas collected at 298 K...	63	93	59	3
138. The boiling point of oxygen is...	48	94	58	3

Display 52
Interpretation Panel Ratings of Student Achievement
by Individual Questions Together with Summary Question Data
Provincial Results - Chemistry

Chemical Reactions - Quantitative	*P Value*	*OTL*	*TPC*	*IPR*
Knowledge				
10. In balancing a chemical equation, one...	39	97	64	2
45. When gases combine chemically or are...	33	87	51	2
Application				
11. The volume of O2 (oxygen), compared to...	43	84	58	3
18. Potassium chlorate (KC1O3) is decomposed...	61	99	71	3
48. The reaction between H2 (hydrogen) and...	37	99	65	2
49. Hydrogen gas reacts with hot copper(II)...	50	98	60	3
51. Carbon disulphide (CS2) burns in air...	43	98	58	3
61. Which one of the following equations...	82	99	82	4
77. The unbalanced equation representing...	80	98	73	4
92. Nitogen gas (N2) and hydrogen gas (H2)...	55	90	51	3
94. What volume of dry oxygen, at STP...	50	91	58	3
130. What mass of CaCO3 (calcium carbonate)...	55	98	63	3
132. In the reaction described by the...	60	99	68	3
133. Hydrogen and oxygen gases combine to...	50	92	62	3
140. N2(g)... What volume of nitrogen reacts...	48	93	57	2
Higher Order Skills				
17. A strip of Zn (metallic zinc) was weighed...	78	93	64	5
52. Consider the equation ...	35	76	41	2
64. During the electrolysis of water,...	15	48	32	2
91. Methanol (CH3OH) burns according to the...	53	89	48	3
131. The volume of uncombined gas remaining...	17	82	40	1

Display 52
Interpretation Panel Ratings of Student Achievement
by Individual Questions Together with Summary Question Data
Provincial Results - Chemistry

Chemical Reactions - Qualitative	*P Value*	*OTL*	*TPC*	*IPR*
Knowledge				
19. An example of an endothermic process...	39	88	52	1
50. When metals are burned in oxygen...	48	73	47	2
66. One mole of a pure substance contains...	94	100	88	5
78. Breaking a compound down into its...	90	99	77	5
100. The molar mass of A1 (CO3)3 is...	79	100	80	4
108. Which of the following elements will...	33	57	35	2
127. The Roman numeral which would be...	64	100	70	3
Application				
4. The number of moles of Zn in 1.41 g...	84	99	73	5
9. A given element that burns readily...	74	98	63	4
20. The number of hydrogen atoms in...	55	99	58	3
32. A metal which does NOT readily release...	42	75	45	2
41. How many atoms are represented by...	63	100	83	2
65. Phosphorus, P4, burns in air to form...	78	99	75	5
80. A hydrocrbon gas has a relative molecular...	51	93	56	3
103. One example of an oxide that reacts with...	44	71	46	2
104. The correct formula for manganese(IV)...	54	99	71	2
Higher Order Skills				
3. A compound contains 46.2 percent carbon...	28	86	47	1
43. Given that the relative atomic masses...	63	97	46	5
68. An empty flask (one with all the air...)	50	79	33	4
99. If XBr2 is the formula for a metallic...	44	99	60	2
136. The formula of a metallic fluoride is...	47	99	55	3
137. If alcohol is burned in air and the...	49	79	43	2

Display 52
Interpretation Panel Ratings of Student Achievement
by Individual Questions Together with Summary Question Data
Provincial Results - Chemistry

Solutions	*P Value*	*OTL*	*TPC*	*IPR*
Knowledge				
33. The reaction between gaseous hydrogen...	39	68	42	2
70. A solution which contains an equal...	69	76	60	3
95. When potassium hydroxide reacts with...	47	83	59	2
139. Which of the following substances is...	52	49	30	2
141. The number of moles of KOH (potassium...)	56	84	58	2
Application				
6. 500 mL of a solution contains...	68	84	62	3
16. The ions formed when magnesium bromide...	48	92	62	2
21. Which of the following will form an...	34	73	46	1
39. Which of the following compounds would...	33	50	33	2
40. Some aqueous solutions are strongly basic...	51	79	58	2
71. In the neutralization reaction between...	52	79	51	3
73. The concentration of a solutio...	51	85	57	3
101. The reaction of aqueous solutions...	33	42	30	1
110. What volume of 5.0 mol/L HCl...	53	78	46	4
Higher Order Skills				
47. 1.0 L of a 0.5 mol/L solution of...	25	70	39	1
76. Three moles of sodium hydroxide, NaOH,...	41	72	43	3
111. One gram of sodium chloride, NaCl, is...	41	84	49	3

Student achievement in the extended-response questions were rated as follows:

Question One (Qualitative Analysis)	*Marginal*
Question Two (Acid Rain)	*Satisfactory*
Question Three (Molar Mass of Gas)	*Satisfactory*
Question Four (Alloys)	*Marginal*
Question Five (Plastic Film)	*Strong*

10.5 The Interpretation Panel

Introduction to Chemistry The panel felt that students could understand and apply laws and principles. This was particularly seen in responses to questions 46 and 109. Question 63 was seen as being poorly answered, perhaps due to the fact that many teachers assumed this to be taught prior [Display 49(a)].

Atomic Structure Students did well on recall questions, but had difficulty with concepts of bonding and energy, periodic trends, and the relationship between electron configuration and properties.

Gases and Mole Problems Students did one-step questions generally well, but had much less success in higher-order questions. Students also had difficulty relating names to laws. Question 38 was seen as perhaps offering more than one correct answer.

Chemical Reactions-Quantitative The panel felt that student results were generally satisfactory, with most weaknesses in questions dealing with gases. Question 17 was seen as particularly difficult, with too much distracting material offered. Question 64 was seen as perhaps more relevant to an OAC course, requiring a fairly sophisticated understanding of electrochemistry.

Chemical Reactions-Qualitative Students had a good grasp of molar concepts and balancing equations, but had more difficulty with basic definitions, nomenclature and formula writing.

Solutions Opportunity to learn was generally lower in this domain, perhaps due to the fact that it is often taught late in the year. Students indicated a general understanding of molar relationships, but had problems with the concept of ionization and acids and bases.

Extended-Response Questions

1. Qualitative Analysis: The panel felt that in general, experimental design and organization was weak. The list of equipment given to students may have been more of a distractor than a help.
2. Acid Rain: The panel rated student responses as generally strong in general knowledge, but weak in the theoretical aspects. Social and political awareness was seen as strong.
3. Molar Mass of Gas: The panel saw this as a somewhat more difficult question, but one that was within the scope of most students. Again, the list of equipment was seen as a possible distractor, rather than a help. The level of non-response was high.
4. Alloys: Student responses were seen as indicating a need for much more experience in solving this kind of problem.
5. Plastic Film: The panel was generally pleased with student responses to this question.

10.5 Student Attitudes Towards Science

Each student also answered questions related to attitudes to the chemistry course. Since each of the five booklets contained different sets of questions, attitudinal data was collected for six different sets of questions (one booklet contained two sets of questions). One fifth of the students in

each school answered each collection of questions.

Six sets of questions (or scales) were responded to by students:

Science and Experiments	(12 questions)
Career in Science	(7 questions)
Gender and Science	(4 questions)
Science and Society	(14 questions)
Science as a Process	(11 questions)
Chemistry in Schools	(8 questions)

Laboratory Work: More than 3 out of every 4 students value hands-on laboratory work both as an enjoyable pursuit and as an aid to understanding concepts, whereas they spend about one quarter of their class time "performing, discussing and writing up" experiments.

Science as a Career for both Males and Females: Slightly over half of the students perceived the value of scientific training in future careers. A large majority saw gender as no factor in determining ability in, or need for, scientific pursuits.

Science in Society: A majority (60%) of students indicated that science is an important factor in the development of our country and the improvement of our standard of living. Their opinions are, however, divided on the costs involved both in terms of public money spent on scientific endeavors and on the effect on the environment.

The Processes of Science: A number of questions were asked about the students' appreciation and understanding of the nature of scientific processes. While the dynamic, changing, creative nature of science was appreciated, students were divided on an understanding of the scientific approach to problem solving. A significant number of students (about 60% of all students) felt that scientific problem solving involved the applications of strict rules that had been memorized.

Attitudes toward Chemistry: A majority of students perceived Chemistry as a difficult, yet an enjoyable and interesting subject. Most students also saw Chemistry as being relevant to their lives.

Display 53 provides details of the responses given to these questions by the students in the provincial sample. Questions are arranged by attitude scale and the percentage of students providing each response option is presented.

Display 54 provides a summary of the percentage of students providing positive, neutral or negative attitudes towards science for each scale. The categorizations were made by identifying the range of possible responses for each scale and identifying the percentage of students falling in the highest, middle, and lowest third of the range.

Display 55 provides information concerning the range of student attitudes among schools.

Display 53
Percentage of Students Providing Various Response Options for the Attitude Scales Items
Provincial Results - Chemistry

Attitude Scale *Science and Experiments*	*Student Responses*				
	Strongly Disagree	*Dis-Agree*	*Un-Decided*	*Agree*	*Strongly Agree*
I prefer to read why things happen rather than to do an experiment to find out.	29	43	12	12	3
I would rather watch the teacher do experiments than to do them myself.	35	45	9	8	3
It is better to be told scientific facts than to try to discover them from experience.	25	45	17	10	3
Doing experiments is too slow a way to learn science.	23	54	14	8	1
Doing experiments did not help me learn science.	33	53	7	5	2
I would like to spend more time doing experiments.	2	13	21	47	17
I find that doing experiments helps me to understand science.	2	8	14	57	19
I would rather do experiments myself than watch other students do them.	3	13	11	47	26
I would rather work with someone else than do experiments by myself.	3	6	11	49	32
I like to try out new ideas by doing science experiments.	2	10	25	49	14
I am interested in the unexpected results that sometimes occur in science experiments.	2	7	13	57	20
I enjoy demonstrations or experiments which give unexpected results.	1	5	13	54	25

Display 53 (continued)
Percentage of Students Providing Various Response Options for the Attitude Scales Items
Provincial Results - Chemistry

Attitude Scale Careers in Science	*Student Responses*				
	Strongly Disagree	*Dis-Agree*	*Un-Decided*	*Agree*	*Strongly Agree*
Working in a science laboratory would be an interesting way to earn a living.	5	13	21	50	11
In the future most jobs will require a knowledge of science.	1	12	16	52	17
People who understand science are better off in our society.	4	23	21	40	11
It is important to know science in order to get a good job.	8	44	18	25	5
Science is a very good field for creative people to be in.	5	19	21	43	12
In my future career I would like to use the science I learned in school.	6	18	26	33	16
People who work with modern inventions such as computers have more interesting jobs.	16	46	18	15	4

Display 53 (continued)
Percentage of Students Providing Various Response Options for the Attitude Scales Items
Provincial Results - Chemistry

Attitude Scale Gender and Science	*Student Responses*				
	Strongly Disagree	*Dis-Agree*	*Un-Decided*	*Agree*	*Strongly Agree*
Men make better scientists and engineers than women.	52	24	11	6	7
Boys have more natural ability in science than girls.	46	28	12	8	5
Boys need to know more science than girls.	51	32	9	5	2
A woman needs a career just as much as a man does.	3	6	8	28	54

Display 53 (continued)
Percentage of Students Providing Various Response Options for the Attitude Scales Items
Provincial Results - Chemistry

Attitude Scale *Science and Society*	*Student Responses*				
	Strongly Disagree	*Dis-Agree*	*Un-Decided*	*Agree*	*Strongly Agree*
Science is useful for solving the problems of everyday life.	2	10	13	58	17
Science has ruined the environment.	11	42	27	17	3
Science is very important for a country's development.	2	3	6	52	37
Money spent on science is well worth spending.	1	4	19	56	20
Much of the anxiety in modern society is due to science.	4	31	36	24	6
Public money spent on science in the last few years has been used wisely.	2	16	51	28	3
Scientific inventions improve our standard of living.	1	4	10	56	29
The government should spend more money on scientific research.	2	13	34	35	15
Scientific inventions have made the world too complex.	9	50	19	17	5
Scientific inventions have increased tensions between people.	5	24	26	37	9
Science will help to make the world a better place in the future.	3	9	30	42	16
Scientific discoveries do more harm than good.	14	50	29	5	1
Science and technology are the causes of many of the world's problems.	7	31	24	31	7
I want to learn more about the world we live in.	1	2	7	48	38

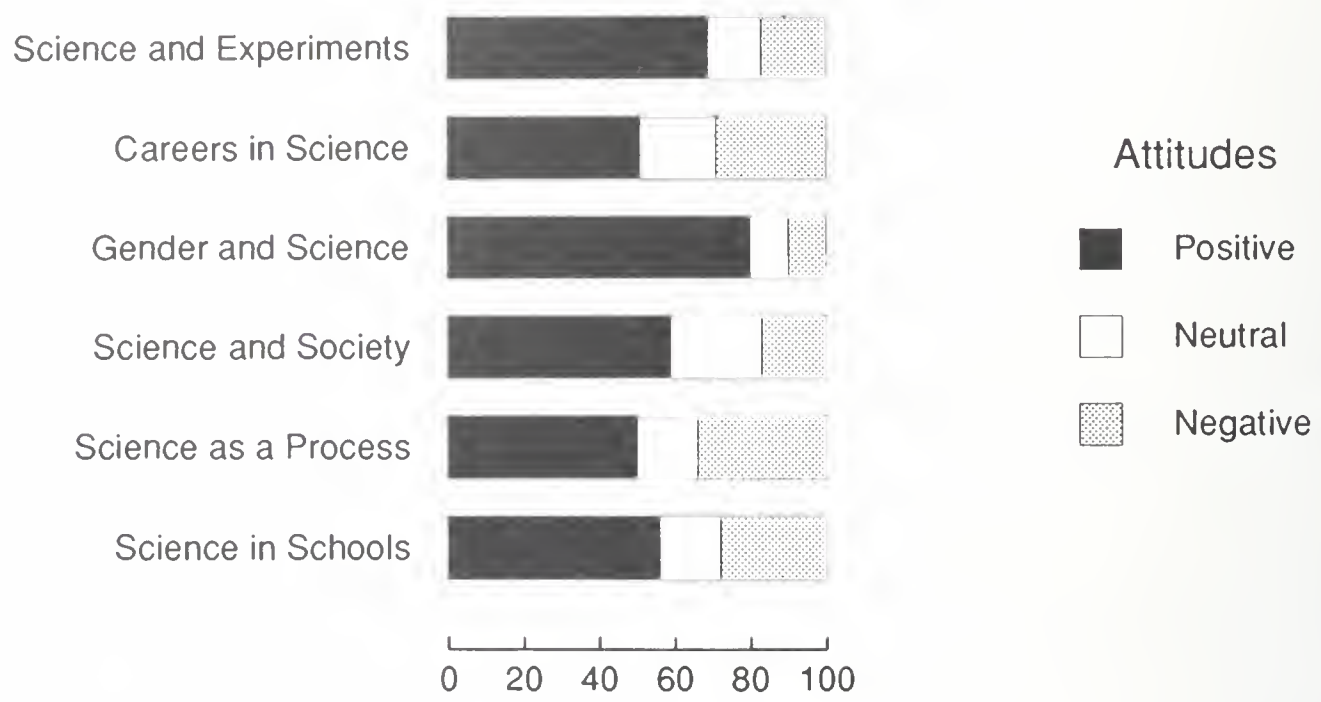
Display 53 (continued)
Percentage of Students Providing Various Response Options for the Attitude Scales Items
Provincial Results - Chemistry

Attitude Scale *Science as a Process*	*Student Responses*				
	Strongly Disagree	*Dis-Agree*	*Un-Decided*	*Agree*	*Strongly Agree*
Science will change rapidly in the near future.	1	7	17	54	21
Science is a good field for creative people.	4	17	14	52	13
There is little place for originality in solving science problems.	9	34	20	28	8
New discoveries in science are constantly being made.	1	3	6	61	30
Science helps one to think according to strict rules.	3	22	26	40	9
Estimating is an important science skill.	6	19	15	51	9
There are many different ways to solve most science problems.	3	24	16	49	7
Learning science involves mostly memorizing.	7	36	13	33	11
In science, problems can often be used to solve a science problem.	27	47	13	11	1
Trial and error can often be used to solve a science problem.	4	16	18	53	10
There is always a rule to follow in solving a science problem.	2	18	16	50	11

Display 53 (continued)
Percentage of Students Providing Various Response Options for the Attitude Scales Items
Provincial Results - Chemistry

Attitude Scale Chemistry in Schools	*Student Responses*				
	Strongly Disagree	*Dis-Agree*	*Un-Decided*	*Agree*	*Strongly Agree*
If properly taught, almost all students could learn Chemistry.	3	16	10	56	16
Chemistry is an enjoyable school subject.	6	16	22	48	8
The Chemistry taught at school is interesting.	4	17	19	53	7
Chemistry is a difficult subject.	2	26	13	45	13
Chemistry is difficult when it involves calculations.	8	39	12	30	11
Chemistry is difficult when it involves handling apparatus.	17	66	9	6	1
There are too many facts to learn in Chemistry.	4	32	22	33	8
Chemistry is relevant to life.	3	9	21	46	20

Display 54
Percentage of Students Indicating Positive, Neutral, and Negative Attitudes Towards Science on the Various Attitude Scales
Provincial Results - Chemistry



11. CURRICULUM MANAGEMENT

A separate questionnaire inquired into approaches to curriculum management at the school level. Curriculum management was seen to consist of three components: review, development, and implementation. The person responsible for managing curriculum, usually the science department head, was asked to provide details concerning this process. The data is presented in a series of 10 displays, focussing on the components of Review, Development and Implementation.

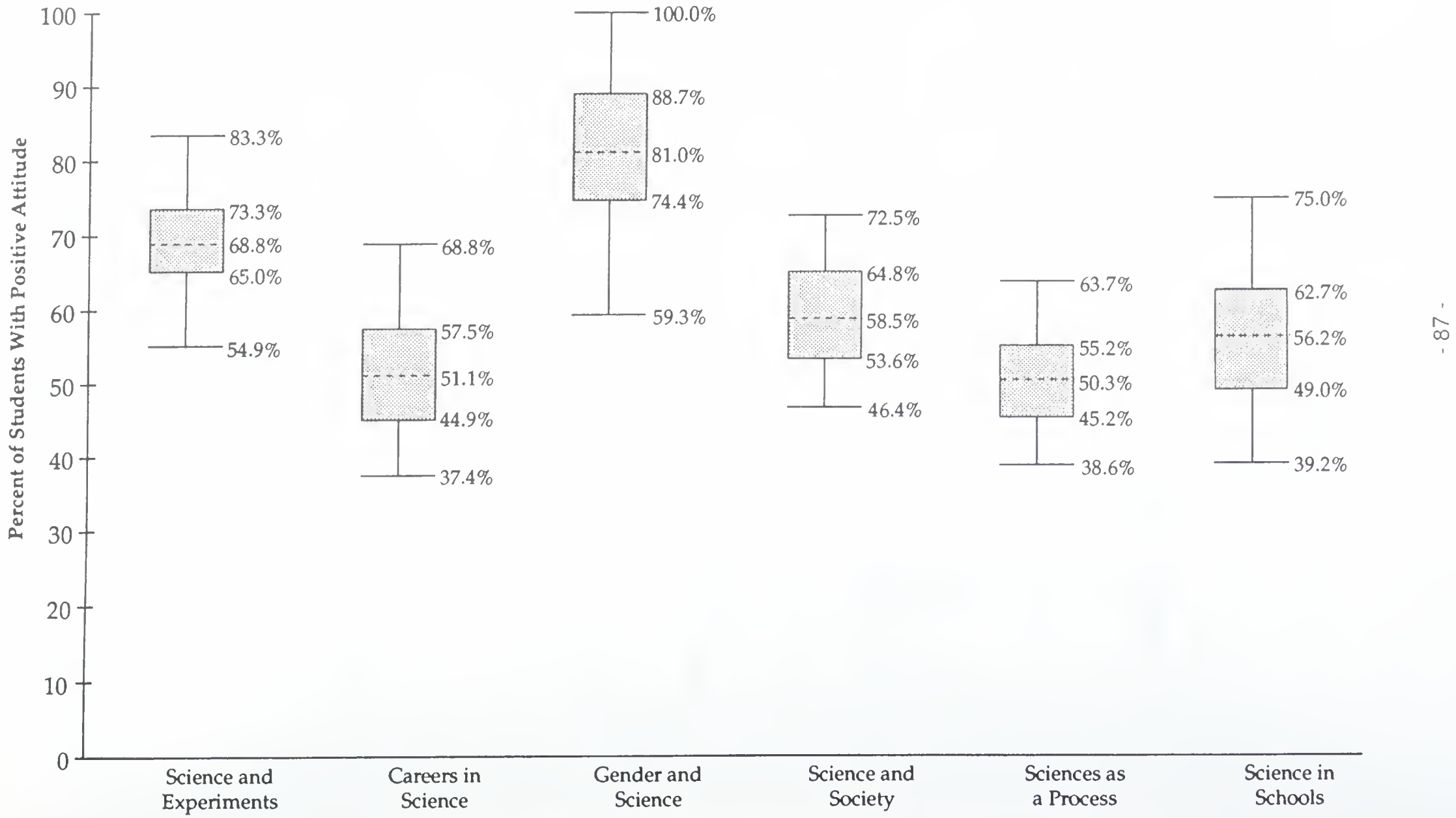
11.1 REVIEWS AT THE LOCAL LEVEL

Department heads reported the occurrence of their most recent review and this data is presented in **Display 56**. Nearly half of the schools reported a course review taking place within the last three years, but 34% reported no review at all.

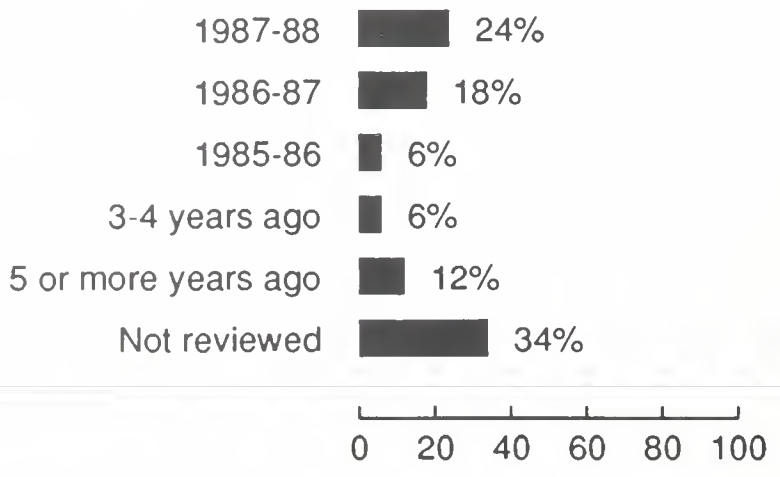
If a review did not occur, the respondent was asked to omit the remaining questions. If a review did take place, the process by which the review was conducted was indicated. **Display 57** shows the percentage of schools reporting the procedure by which the most recent course review was con-

Display 55

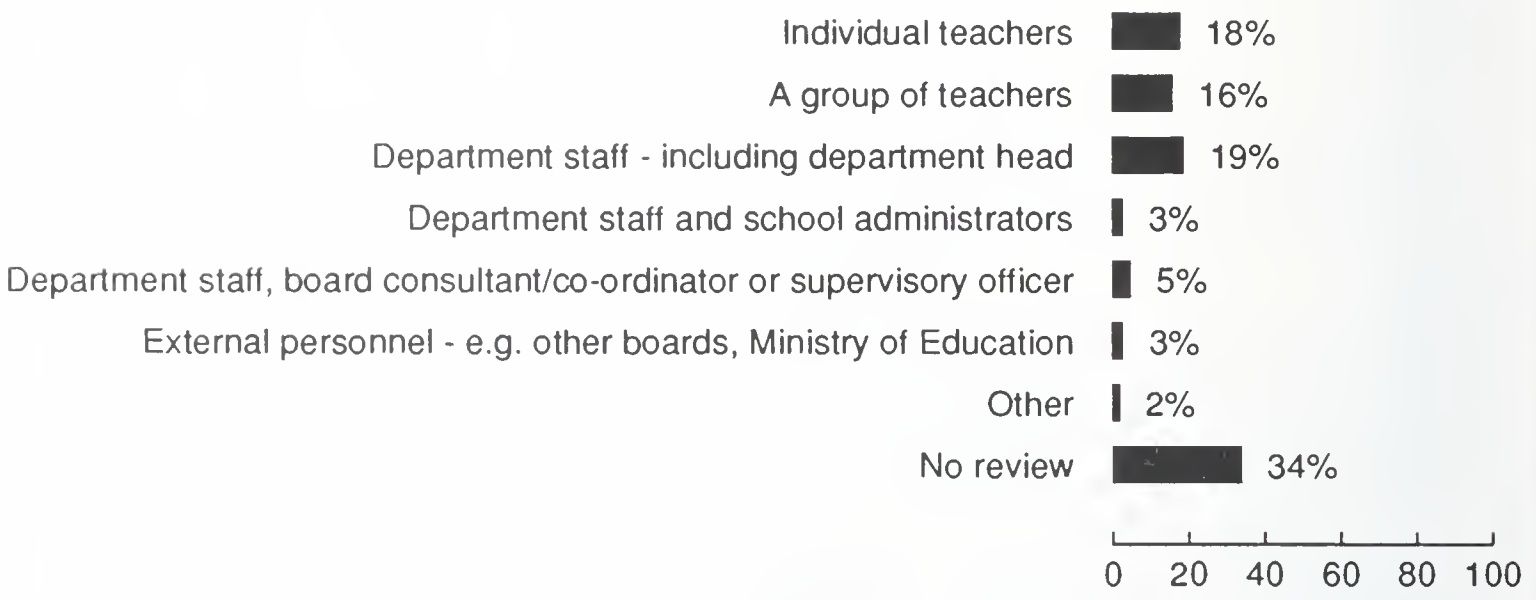
Variation Among Schools in Average Student Attitudes Towards Science



Display 56
The Review Process: Percentage of Schools Reporting the Occurrence of Their Most Recent Course Review
Provincial Results - Chemistry



Display 57
The Review Process: Percentage of Schools Reporting Procedure by Which Most Recent Course Review Was Conducted
Provincial Results - Chemistry

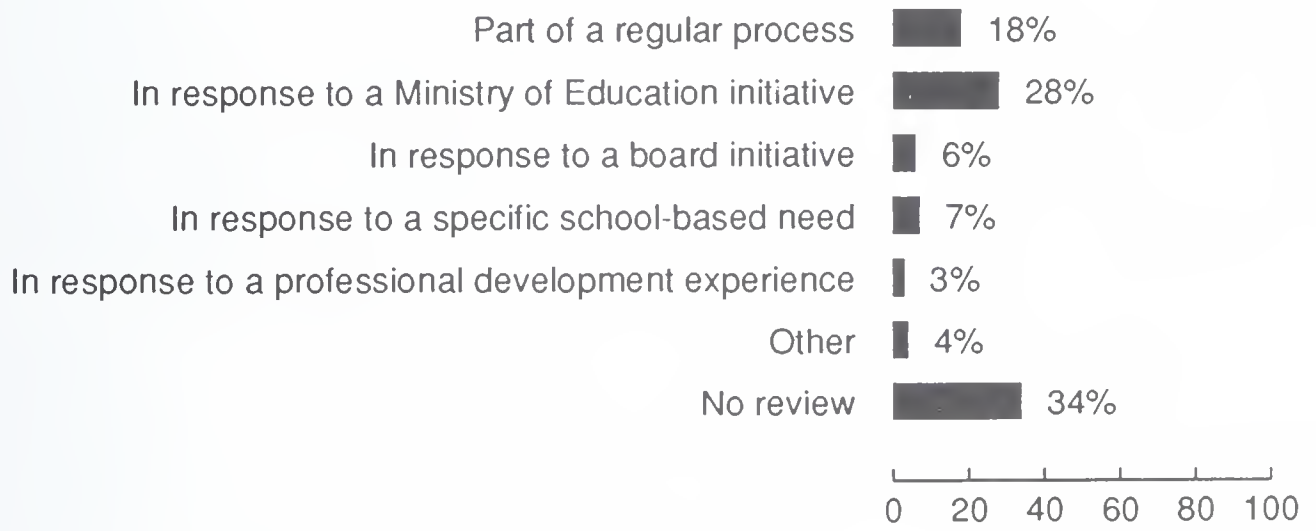


ducted. More than half of the schools reported reviews taking place within the school departments. Ten percent reported reviews being conducted by out of school agencies.

There are a number of reasons which can prompt a course review. Choosing from six options, department heads indicated the single most important reason for instituting a course review. **Display 58** shows the percentage of respondents reporting each of these reasons for the most recent review. The most common initiative reported was the Ministry of Education. This is consistent with the need for a review prior to the implementation of the new guideline. In 18% of schools the review process was part of regular curriculum procedures.

Other aspects of the review process include the influence of various sources on the decision to conduct a review and the resources used to conduct the review. Department heads reported on the degree of influence exerted by various sources, including students, teachers, and board officials, on the initiation of the review. **Display 59** presents the percentage of department heads reporting this

Display 58
The Review Process: Percentage of Schools Reporting the Single Most Important Reason for Most Recent Course Review
Provincial Results - Chemistry



Display 59
The Review Process: Percentage of Schools Reporting the Level of Influence Exerted by Various Sources On the Initiation of the Course Review
Provincial Results - Chemistry

Variety of Individuals	*Degree of Influence*		
	None	*Some*	*Much*
Students	71	24	6
Teachers	28	29	44
Department Heads	16	38	46
Principal/Vice Principal	69	19	12
Consultant/Co-ordinator	68	24	8
Board Supervisory Official	72	14	13
Ministry of Education Official	71	14	14
Trustees	95	4	1
Community	94	6	0
Other	97	1	3

data while **Display 60** shows the level of use of resources used in conducting the course review. Teachers and Department Heads exerted by far the most influence for initiating the review. Ministry guidelines were the most commonly cited resource, followed by the existing school course of study. Educational research and material from professional organizations were little used, reflecting the locally-based nature of most of the reviews which took place.

11.2 The Course Development Process

Inquiries were also made concerning the course development process. **Display 61** summarizes the process by which development was undertaken. While 52% of schools reported no course development or revision, that which did take place was done very much at the local level.

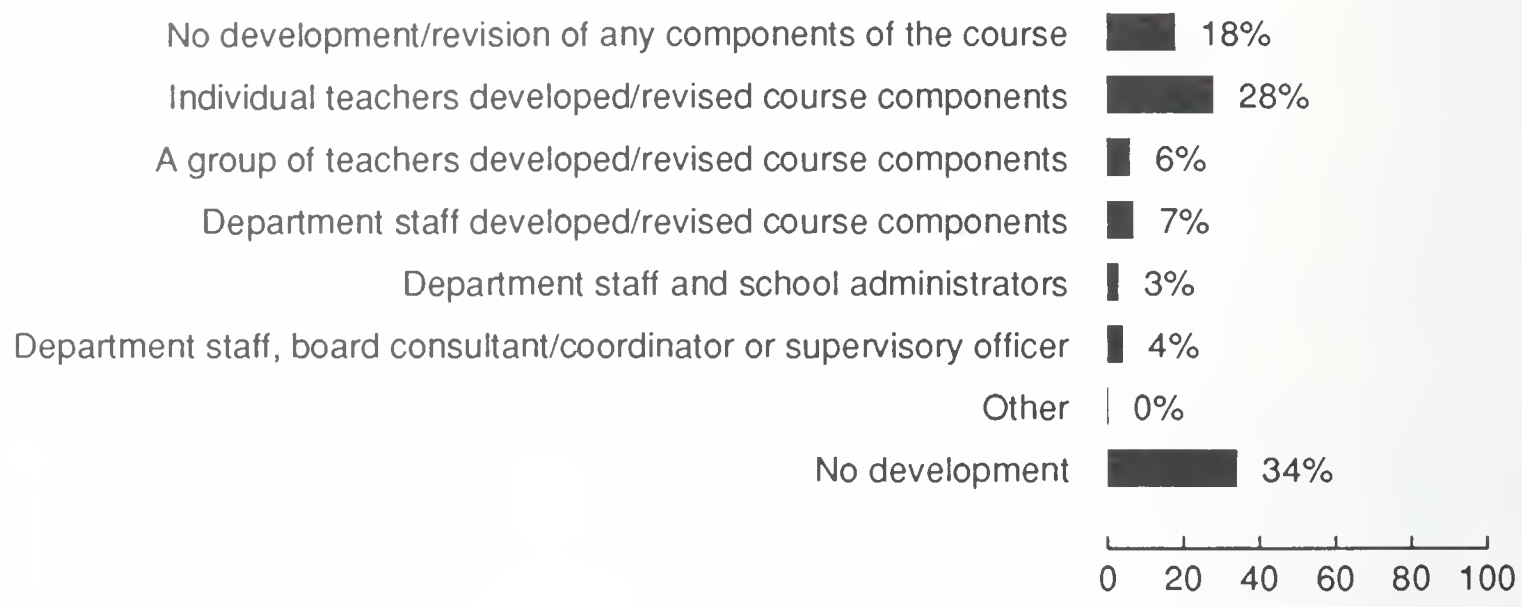
Display 62 shows the level of involvement of various individuals in recent course development. The classroom teacher and department head were most involved in the process with little or no involvement of people outside of the science department.

Display 63 provides the percentage of schools using varying levels of resources in the development. Little use is made of material outside of the school other than Ministry guidelines.

Display 60
The Review Process: Percentage of Schools Reporting Varying Levels of Use of Resources in the Review
Provincial Results - Chemistry

Types of Resources	*Extent of Usage*		
	None	*Some*	*Much*
Ministry of Education Guidelines	3	24	72
The School Board's Program Documents	44	32	24
Other Boards' Program Documents	69	24	8
Your School's Existing Course of Study	3	44	53
Other Schools' Courses of Study	60	37	3
Materials from Professional Organizations	57	38	5
Educational Research	62	36	3
Textbooks	21	54	25
Other	95	2	3

Display 61
The Development Process: Percentage of Schools Reporting Process by Which Most Recent Development Was Undertaken
Provincial Results - Chemistry



11.3 THE IMPLEMENTATION PROCESS

A variety of factors have been identified as influencing the implementation of course changes. Department heads indicated whether these factors had been positive, negative or neutral influences upon the implementation of changes. **Display 64** shows that the most positive influence was a coaching-type experience, with clear timelines and specific expectations outlined. These same timelines and specifics also provided some hindrance to the process, but the main obstacle was the sheer number of courses requiring change.

Display 65 summarizes the results of the review, development and implementation process upon various course components. These components include the teaching rationale, sequence and timing

of objectives, modifications for exceptional students, and Canadian science and scientists. The most extensive changes implemented were in sequence and timing of objectives, lab activities, safety, and resources. Little changes were made in areas such as mode of delivery, and teaching strategies.

Department heads were asked to judge the current and desired influence of principals and department heads on the curriculum management process. This data is found as **Display 66**, and reflects the important role that the department head plays as a change agent in the secondary school today.

Display 62
The Development Process: Percentage of Schools Reporting the Level of Involvement of Various Sources with Recent Course Development
Provincial Results - Chemistry

Individual/Groups	*Extent of Involvement*		
	None	*Some*	*Much*
Students	77	22	2
Teachers	4	14	82
Department Heads	13	34	53
Principal/Vice Principal	86	14	0
Consultant/Co-ordinator	70	25	5
Board Supervisory Official	89	10	1
Ministry of Education Official	84	14	2
Trustee	99	1	0
Community	97	4	0
Other	97	0	3

Display 63
The Development Process: Percentage of Schools Reporting Varying Levels of Use of Resources in the Review
Provincial Results - Chemistry

Types of Resources	*Extent of Usage*		
	None	*Some*	*Much*
Ministry of Education Guidelines	1	18	81
The School Board's Program Documents	46	35	19
Other Boards' Program Documents	64	31	4
The School's Existing Course of Study	3	43	55
Other Schools' Courses of Study	57	40	4
Materials from Professional Organizations	50	46	4
Educational Research	63	36	2
Textbooks	18	55	27
Other	98	0	2

12. STANDARD ERRORS ASSOCIATED WITH THE STUDENT ACHIEVEMENT RESULTS PRESENTED IN THIS REPORT

Since multiple-matrix sampling was used to collect student achievement data, each question as well as each set of questions were answered by one fifth of the students in the provincial sample. The results from these samples of students are assumed to represent the achievement levels that would have been obtained had all students attempted all questions.

There is some error of measurement associated with this approach and **Display 67** presents the standard errors of measurement associated with the provincial sample's student achievement results. Confidence intervals of at least plus/minus one standard error should be constructed around the levels of student achievement seen in the provincial sample. These intervals identify the possible range of the provincial sample's achievement scores had all students attempted all questions. The document *Guidelines for Determining the Accuracy of Student Achievement Scores* provides further details concerning the meaning of standard errors.

Display 64
The Implementation Process: Percentage of Schools Rating Various Factors as Either Positive, Negative, or Neutral Influences in the Implementation of Course Changes
Provincial Results - Chemistry

Types of Factors	*Type of Influence*		
	Positive	*Negative*	*Neutral*
Number of Courses to Change	11	57	32
Board Support	44	4	52
Community Support	7	0	93
Timeline for Change	52	24	25
Clarity of the Change	51	11	38
Quality and Availability of Materials	44	25	31
Principal/Vice Principal Involved/Support	33	2	65
Consultant/Co-ordinator Involved/Support	46	0	54
Relevance and Amount of In-service	33	6	61
Teacher to Teacher Interaction/Coaching	75	4	22
Availability/Use of External Resources	43	9	48

Display 65
Summary of Review, Development, and Implementation Practices:
Percentage of Schools Reporting Various Course Components
Influenced by the Curriculum Management Process
Provincial Results - Chemistry

Components	*Component Reviewed*		*Component Developed*		*Changes Implemented*			
	Yes	*No*	*Yes*	*No*	*None*	*Little*	*Moder-ate*	*Exten-sive*
Rationale for Teaching Course	70	30	57	43	38	31	29	2
Sequence and Timing of Objectives	94	6	91	9	9	22	49	20
Language Across the Curriculum	55	45	46	54	50	32	16	2
Equity (sex) and Multiculturalism	41	59	34	66	61	23	15	1
Modifications for Exceptional Students	49	51	41	59	54	24	18	4
Career Awareness	71	29	60	40	35	30	32	4
Canadian Science and Scientists	52	48	49	51	45	30	20	5
Laboratory Activities	92	8	87	13	12	25	50	14
Safety	90	10	78	22	21	33	33	13
Teaching Strategies	92	8	86	14	13	39	43	5
Mode of Delivery	75	25	67	33	23	45	29	3
Resources - texts, other print materials, lab equipment	90	10	77	23	19	32	35	14
Student Assessment Strategies	86	14	80	20	18	29	45	8
Other	3	97	2	98	96	3	1	1

Display 66
Average Levels of Reported Current and Desired Influence of Principals and Department Heads Upon the Curriculum Management Process as Reported by Department Heads
Provincial Results - Chemistry

Stages of Curriculum Management Process	*Degree of Influence*			
	Department Head		*Principal*	
	Current	*Desired*	*Current*	*Desired*
Determining the Need for a Review of the Course	2.3	2.5	1.6	1.8
Reviewing Components of the Course	2.3	2.5	1.3	1.5
Developing or Revising Components of the Course	2.2	2.4	1.2	1.4
Implementing New or Revised Components of the Course	2.4	2.5	1.3	1.6

Degree of Influence: 1 - None 2 - Some 3 - Much

Display 67
Standard Errors Associated with the Student Achievement Results for this School
English – Chemistry

Student Achievement Statistic	*Standard Error*
For a question with 10% correct responses	0.6
For a question with 20% correct responses	0.8
For a question with 30% correct responses	1.0
For a question with 40% correct responses	1.0
For a question with 50% correct responses	1.1
For a question with 60% correct responses	1.0
For a question with 70% correct responses	1.0
For a question with 80% correct responses	0.8
For a question with 90% correct responses	0.6
For the average on content domain 1	0.3
For the average on content domain 2	0.2
For the average on content domain 3	0.2
For the average on content domain 4	0.2
For the average on content domain 5	0.2
For the average on content domain 6	0.2
For the average on process domain 1	0.2
For the average on process domain 2	0.1
For the average on process domain 3	0.2

Based on matrix sampling of 11169 students.

13. SUMMARY OF DISPLAYS

Display 68 provides a summary of the tables, graphs, and charts reported at the three levels of the review: school, board and province.

14. LINKAGES

Correlation of Teacher Reports of Coverage and Student Achievement

The large scale assessment literature indicates that student opportunity-to-learn the content and skills involved with the assessment instruments is usually the single best predictor of student achievement. In the case of the present review this also proved to be the case.

Display 69 - The Magnitude of Association Between Teachers' Reports of Coverage and Student Achievement - presents the correlations of teachers' reports of student opportunity-to-learn (taught, reviewed, or assumed taught prior) with student achievement on the 100 selected response (objective) questions. The data presented is classified by the three process levels and six content areas used throughout this review.

The bars on the graph represent the degree of association for the provincial sample of chemistry classes between teacher reports of higher coverage and higher student achievement on the questions. The graph does not indicate anything about the absolute level of coverage or achievement (see **Displays 20-25** for data concerning opportunity-to-learn and **Displays 44-48** for student achievement results), but rather the relationship between reports of coverage and student achievement.

As shown in **Display 69**, all the correlations were both statistically significant and practically significant. **The correlation coefficient squared indicates the amount of variation in student achievement accounted for by coverage.** For example, more than 10% ($.37^2$) of the variation in student achievement in the Higher-order Skills questions could be accounted for by teachers' coverage of these questions.

Similarly, for the Solutions content area a full 25% (0.5^2) of the variation among classes in student achievement could be accounted for by differences in teachers' reports of coverage of the material assessed by these questions.

Congruence of Teachers' Predictions with Levels of Student Achievement Achievement

Display 70 presents the levels of actual attained student achievement in the six content areas and teachers' predicted levels. Teachers tended to overestimate students' achievement levels. For the questions concerned with Atomic Structure teachers' overestimated a full 13% percentage points, and overestimated Gases and Moles, and Quantitative Reactions achievement by about 10 percentage points.

Display 68
Summary Guide of Displays for the Senior Division Chemistry Provincial Review Found in the Provincial, Board and School Results

P = Provincial Results
B = Board Results
S = School Results

PBS	*Display 1.* Participation Rates
PB	*Display 2.* Percentage of Teachers with Varying Years of Teaching Experience and Experience Teaching Advanced Level Science
PB	*Display 3.* Teachers' Reports of Their Educational Background and Special Qualifications
PB	*Display 4.* Percentage of Teachers Using Various Methods for Keeping Knowledge Up-To-Date
PB	*Display 5.* Percentage of Classes Reported Taught at Varying Class Enrollments
PBS	*Display 6.* Percentage Gender Enrollment in the Senior Division Science Course
PBS	*Display 7.* Student Reports of Future Educational Plans and Whether Science Courses are Expected in These Future Plans
PBS	*Display 8.* Percentage of Students Reporting Use of a Computer for Various Activities at Home and Hours of Use of a Computer at School Per Week
PB	*Display 9.* Student Reports of Frequency of Various Classroom Activities on the Parts of Their Teachers
PBS	*Display 10.* Student Reports of Number of Hours Spent Per Week on Homework in Science and Homework in All Subject Areas
PBS	*Display 11.* Percentage of Students Reporting Varying Amounts of Television Watching and Reading Each Day
PBS	*Display 12.* Percentage of Students Reporting Various Employment Activities and Number of Hours Spent Per Week Working
PBS	*Display 13.* Percentage of Students Reporting Various Out-of-School Activities Concerned With Science

PBS	*Display 14.* Percentage of Students Reporting Various Levels of Involvement in School Science Fairs
P	*Display 15.* Analysis of the Courses of Study: Percentage of Schools Containing Various Components
PB	*Display 16.* Percentage of Teachers Reporting Inclusion of Various Components in their School's Courses of Study and the Amount of Influence of these Components On Their Teaching
PB	*Display 17.* Percentage of Teachers Reporting Varying Number of Hours Spent on Topics
P	*Display 18.* Box and Whiskers Chart Indicating Variation Among Schools in Average Time Spent on Various Topics
PB	*Display 19.* Teachers' Average Report of Percentage of Class Time Spent in Various Instructional Activities
PBS	*Display 20.* Percentage of Students Reported by Teachers as Having Had the Opportunity-to-Learn the Science Necessary to Answer the Questions Correctly by Process Level
PBS	*Display 21.* Percentage of Students Reported by Teachers as Having Had the Opportunity-to-Learn the Science Necessary to Answer the Questions Correctly by Content Domain
PBS	*Display 22.* Percentage of Students Reported by Teachers as Having Had the Opportunity-to-Learn the Science Necessary to Answer the Questions Correctly by Process Level and Content Domain
PB	*Display 23.* Percentage of Teachers Indicating Whether the Science Necessary to Answer Each Question Had Been Taught or Reviewed, and If Not, the Reasons For Not Teaching or Reviewing the Science
P	*Display 24.* Box and Whiskers Chart Indicating Variation Among Schools in Average Student Opportunity-To-Learn: Questions Grouped by Process Level
P	*Display 25.* Box and Whiskers Chart Indicating Variation Among Schools in Average Student Opportunity-To-Learn: Questions Grouped by Content Domain
PB	*Display 26.* Percentage of Teachers Reporting Varying Frequency of Use of Teaching Resources
PB	*Display 27.* Percentage of Teachers Reporting Varying Frequency of Use of Teaching Approaches
PB	*Display 28.* Percentage of Teachers Reporting Varying Frequency of Evaluation for Diagnostic, Formative, and Summative Purposes
PB	*Display 29.* Percentage of Teachers Reporting Varying Emphasis upon Norm-Referenced, Criterion-Referenced, Individualized Ability, and Growth-Based Approaches to Evaluation

PB	*Display 30.* Percentage of Teachers Reporting Varying Frequency of Use of Various Evaluation Methods
PB	*Display 31.* Proportional Weights Assigned to Various Evaluation Practices by Teachers for Assigning Students' Final Grades
PB	*Display 32.* Percentage of Teachers Reporting Varying Student Classroom Use of Calculators and Computers
PB	*Display 33.* Percentage of Teachers Reporting Varying Amounts of Homework Assigned Each Week
PB	*Display 34.* Percentage of Teachers Reporting Varying Frequency of Student Activities During the Course Concerned With Experimental Method
PB	*Display 35.* Percentage of Teachers Reporting Varying Frequency of Instruction Focussed Upon the Experimental Method
PB	*Display 36.* Percentage of Teachers Placing Varying Levels of Importance Upon Various Learning Objectives Concerned With Experimental Method
PB	*Display 37.* Percentage of Teachers Reporting Use of Various Strategies for Teaching Boyle's Law
PB	*Display 38.* Percentage of Teachers Reporting Use of Various Evaluation Techniques for Assessing Student Learning of Boyle's Law
PB	*Display 39.* Percentage of Teachers Reporting Student Access to Computers in the School and in the Classroom
PB	*Display 40.* Percentage of Teachers Reporting Varying Use of Computer Programs in the Classroom
PB	*Display 41.* Percentage of Teachers Reporting the Availability and Amount of Use of Various Ontario Educational Software Service Programs
PB	*Display 42.* Percentage of Teachers Reporting Various Sources of Their Training in Instructional Use of Computers and Hours Received in Such Training
P	*Display 43.* Box and Whiskers Chart of Teacher Reports of the Percentage of Time That Would Be Appropriate for Classroom Use of Computers if the Appropriate Software was Available
PBS	*Display 44.* Percentage of Students Answering the Questions Correctly by Process Level
PBS	*Display 45.* Percentage of Students Answering the Questions Correctly by Content Domain
PBS	*Display 46.* Percentage of Students Answering the Questions Correctly by Process Level and Content Domain
P	*Display 47.* Box and Whiskers Chart Indicating Variation Among Schools in Average Student Achievement: Questions Grouped by Process Level

P	*Display 48.* Box and Whiskers Chart Indicating Variation Among Schools in Average Student Achievement: Questions Grouped by Content Domain
PBS	*Display 49.* Detailed Item Analysis for Student Achievement Questions
PS	*Display 50.* Percentage of Student Responses Falling Within Various Response Categories for the Components of the Extended Response Achievement Questions by Content Domain and Process Level
P	*Display 51.* Interpretation Panel Ratings of Student Achievement by Content Domain and Process Level
P	*Display 52.* Interpretation Panel Ratings of Student Achievement by Individual Question Together with Summary Question Data
PBS	*Display 53.* Percentage of Students Providing Various Response Options for the Attitude Scales Items
PBS	*Display 54.* Percentage of Students Indicating Positive, Neutral and Negative Attitudes Towards Science on the Various Attitude Scales
P	*Display 55.* Box and Whiskers Chart Indicating Variation Among Schools in Average Student Attitudes Towards Science
PB	*Display 56.* The Review Process: Percentage of Schools Reporting The Occurrence of Their Most Recent Course Review
PB	*Display 57.* The Review Process: Percentage of Schools Reporting Procedure by Which Most Recent Course Review Was Conducted
PB	*Display 58.* The Review Process: Percentage of Schools Reporting The Single Most Important Reason for Most Recent Course Review
PB	*Display 59.* The Review Process: Percentage of Schools Reporting The Level of Influence Exerted By Various Sources On the Initiation of the Course Review
PB	*Display 60.* The Review Process: Percentage of Schools Reporting Varying Levels of Use of Resources in the Review
PB	*Display 61.* The Development Process: Percentage of Schools Reporting Process by Which Most Recent Development Was Undertaken
PB	*Display 62.* The Development Process: Percentage of Schools Reporting The Level of Involvement of Various Sources With Recent Course Development
PB	*Display 63.* The Development Process: Percentage of Schools Reporting Varying Levels of Use of Resources in Recent Course Development
PB	*Display 64.* The Implementation Process: Percentage of Schools Rating Various Factors as Either Positive, Negative, or Neutral Influences in the Implementation of Course Changes

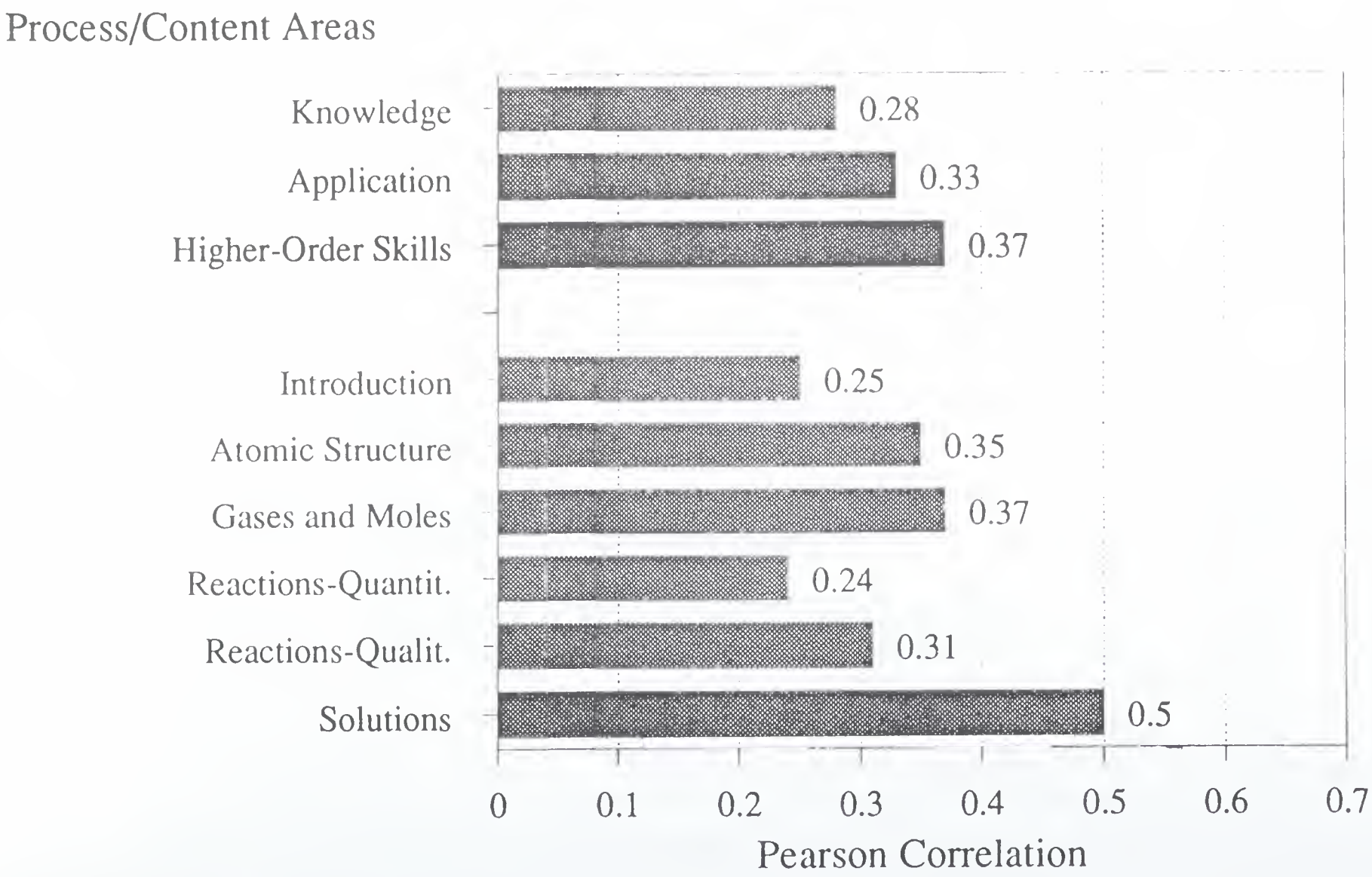
PB *Display 65*. Summary of Review, Development, and Implementation Practices: Percentage of Schools Reporting Various Course Components Influenced by the Curriculum Management Process

P *Display 66*. Average Levels of Current and Desired Influence of Principals and Department Heads Upon the Curriculum Management Process as Reported by Department Heads

PBS *Display 67*. Standard Errors Associated with the Student Achievement Results Presented in These Results

PBS *Display 68*. Summary Guide of Displays for the Senior Division Chemistry Provincial Review

Display 69: Magnitude of Association Between Teachers' Reports of Coverage and Student Achievement



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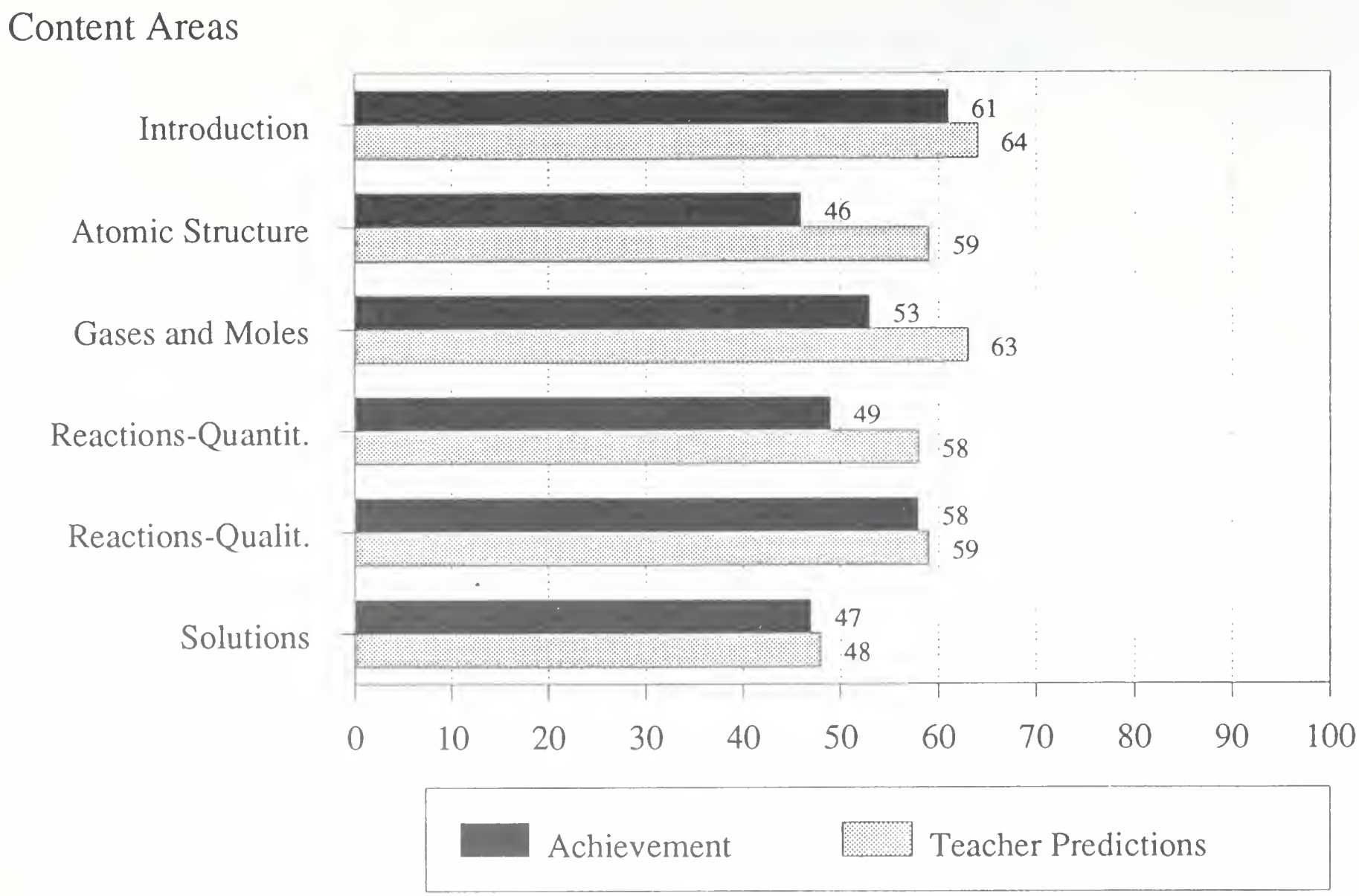
Display 70: Congruence Between Teachers' Predictions and Student Achievement



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ENDNOTES

1 Ontario Ministry of Education(1988). *Curriculum Management Resource Guide.* Toronto: Queen's Printer for Ontario.

2 The study is described in a three-volume Background Study of the Science Council of Canada, *Science Education in Canadian Schools*. Conclusions and recommendations are contained in: *Science for Every Student: Educating Canadians for Tomorrow's World. Report 36* (1984)

3 The SISS study is perhaps best described in two documents:

(i) Connelly, F.M., Crocker, R.K. and Kass, H. (Eds)(1985) *Science Education in Canada: Vol 1 - Policies, Practices and Perceptions.* Toronto: Ontario Institute for Studies in Education.

(ii) Connelly, F.M. (1987). *Ontario Science Education Report Card: Canadian National Comparisons.* Toronto: Queen's Printer for Ontario.

4 Ibid. note 3.

5 Science Teachers' Association of Ontario (1985). *A Rationale for Quality Science Education in the Schools of Ontario.* Kingston: STAO Resource Centre, Queen's University.

6 Extensive reports of the field trials of the Chemistry Pool are found in two documents, released in 1987. As well as field testing the OAIP instruments, many questions were asked of teachers and students regarding the teaching and learning of Chemistry in Ontario.

(i) McLean, L.D. (1987). *Teaching and Learning Chemistry in Ontario in the Senior Division.* Toronto: Ontario Ministry of Education

(ii) Talesnick, I., and McLean, L.D. (1987) Report of the 1983 Field Trials in Chemistry - Senior Division. Toronto: Ontario Ministry of Education.

7 For a complete description of the new Intermediate/Senior science program, see Part I of the guideline: *Science: Intermediate and Senior Divisions (1987). Part I Program Outline and Policy.* The entire guideline consists of 15 parts covering all science courses offered from Grade 7 to OAC at three levels of difficulty.

8 The Primary/Junior science program is described in *Science Is Happening Here - A Policy Statement for Science in the Primary and Junior Divisions.* (1988) Toronto: Ontario Ministry of Education. This new policy is based upon the Statement of Direction released by the Ministry in 1986 - Science in Primary and Junior Education - A Statement of Direction.

9 The SIMS design is described in: McLean, L.D., Raphael, D., and Wahlstrom, M.W. (1985). *Intentions and Attainments in the Teaching and Learning of Mathematics: Report on the Second International Mathematics Study in Ontario.* Toronto: Ontario Ministry of Education.

A more detailed description of the background to the Ontario process is found in a paper presented at the ECS/CDE Conference on Assessment and Curriculum Reform, Boulder, CO., June, 1988.

Raphael, D., Morrow, R., and others. (1988). *A Curriculum Based Approach to Assessment: Provincial Reviews in Ontario.* Toronto: Ontario Ministry of Education, Program Implementation and Review Branch.

10 The relationship between the thirteen goals of Education for Ontario, and the aims of science education, in terms of Curriculum Emphases, is found in Part I of the Intermediate Senior Science Guideline, Section 3.4.

11 Roberts, D. (1982). Developing the Concept of "Curriculum Emphasis" in Science Education. *Science Education*, 66.2, p.245.

12 McLean, (1987) op.cit.

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1. A bond in which atoms share a pair of electrons is a(n)

   a) electrovalent bond

   b) single covalent bond

   c) ionic bond

   d) binary bond

2. The mass of oxygen in 3.0 mol of O_2 gas is

   a) 32 g

   b) 48 g

   c) 64 g

   d) 96 g

3. A compound contains 46.2% carbon and 53.8% nitrogen by mass. At STP, 11.2 L of the gas has a mass of 26 g. The molecular formula of the compound is

   a) CN

   b) CN_2

   c) C_2N_2

   d) C_4N_4

4. The number of moles of Zn in 1.41 g of Zn is

   a) 0.0108 mol

   b) 0.0216 mol

   c) 0.0324 mol

   d) 0.0432 mol

5. The following is a list of the usual charge found on the ions of a series of elements:

   V^{3+} W^{2+} X^{+} Y^{-} Z^{2-}

   Which elements are most likely to be metals?

   a) V and W

   b) V, W and X

   c) X and Y

   d) Y and Z

6. 500 mL of a solution contains 0.20 mol of a salt. The concentration of salt in the solution is

   a) 0.010 mol/L

   b) 0.25 mol/L

   c) 0.40 mol/L

   d) 4.0 mol/L

7. A white solid which has a sharp, constant melting point is decomposed by electrolysis to give a greenish gas and a silvery solid. Attempts to decompose these two substances were not successful. The silvery solid and greenish gas are

   a) elements from a compound.

   b) the components of a homogeneous mixture.

   c) elements from a homogeneous mixture.

   d) the components of a heterogeneous mixture.

8. The elements neon (Ne), sodium (Na), chlorine (Cl) and iodine (I), arranged in order of increasing ionization energy (i.e. the energy required to remove one electron) are

   a) Ne Na Cl I

   b) Na I Cl Ne

   c) Cl I Ne Na

   d) Na Cl I Ne

9. A given element that burns readily in air to form an oxide in which the ratio of O atoms to atoms of the given element is 1:1 is

   a) Mg

   b) V

   c) Si

   d) Cs

10. In balancing a chemical equation, one takes into account

    a) the Law of Definite Proportions.

    b) the Law of Conservation of Mass.

    c) Dalton's Law.

    d) the Law of Constant Composition.

11. The volume of O_2 (oxygen), compared to the volume of H_2 (hydrogen), produced by the electrolysis of water is

    a) 1:2

    b) 1:8

    c) 2:1

    d) 8:1

12. The statement: "the number of molecules in equal volumes of different gases is the same, provided the volumes are measured at the same temperature and pressure", is referred to as

a) Charles's Law.

b) the Law of Constant Composition.

c) Boyle's Law.

d) Avogadro's Principle.

13. A mixture consists of substances associated in

a) definite proportions.

b) equal proportions.

c) any proportions.

d) chemical combination.

14. 5.00 L of dry oxygen (O_2) are collected at 103 kPa and 300K. The volume of the oxygen, at STP is

a) $5.00 \times \frac{103}{101} \times \frac{300}{273}$ L

b) $5.00 \times \frac{103}{101} \times \frac{273}{300}$ L

c) $5.00 \times \frac{101}{103} \times \frac{300}{273}$ L

d) $5.00 \times \frac{101}{103} \times \frac{273}{300}$ L

15. Which one of the following statements is correct?

a) The volume of a given mass of gas (at constant pressure) decreases as its absolute temperature increases.

b) When a gas is cooled, its molecules move faster.

c) At constant volume, an increase in pressure may be due to an increase in the number of molecules.

d) The pressure exerted by a gas at constant volume is not affected by its temperature.

16. The ions formed when magnesium bromide dissolves in water are

a) Mg^{2+}, $2Br^-$

b) Mg^{2+}, Br^{2-}

c) $2Mg^+$, Br^{2-}

d) Mg^+, Br^-

17. A strip of Zn (metallic zinc) was weighed and placed in a beaker containing a solution of $AgNO_3$ (silver nitrate). The next day, a silvery metallic deposit was present in the beaker. The zinc strip was washed, dried and weighed. The liquid was poured off and the metallic residue was also washed, dried and weighed. The data obtained are recorded below:

Mass of zinc strip before reaction	14.26 g
Mass of zinc strip after reaction	13.61 g
Mass of silver produced	2.16 g

$$Zn + AgNO_3 \longrightarrow Ag + Zn(NO_3)_2$$

When the equation is balanced, the coefficients for the substances in the equation given above are, in order of appearance

a) 1, 1, 1, 1

b) 2, 1, 1, 2

c) 1, 2, 2, 1

d) 1, 3, 3, 1

18. Potassium chlorate ($KClO_3$) is decomposed by heating, according to the balanced equation below

$$2KClO_3 \longrightarrow 2KCl + 3O_2,$$

The number of moles of oxygen produced when 10 moles of potassium chlorate is completely decomposed is:

a) 3

b) 10

c) 15

d) 30

19. An example of an endothermic process is

a) condensing a sample of steam

b) melting a sample of ice

c) burning a sample of charcoal

d) freezing a sample of water

20. The number of hydrogen atoms in 0.500 mol of hydrogen gas is

a) 32.0×10^{23}

b) 16.0×10^{23}

c) 6.02×10^{23}

d) 30.1×10^{23}

21. Which of the following will form an acidic solution when dissolved in water?

a) CO_2

b) Na_2O

c) O_2

d) H_2

22. Chemists believe that the chemical properties and chemical activity of an element are related directly to the

a) neutrons in the nucleus of an atom.

b) atomic mass of the atom.

c) valence electrons of the atom.

d) difference between mass number and atomic number.

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31. A 300 mL sample of an ideal gas at 27^0C and 100 kPa pressure is subjected to changes in pressure and temperature. The pressure is doubled and the temperature is changed to 400 K. The new volume will be

a) $300 \times \frac{27}{400} \times \frac{200}{100}$ mL

b) $300 \times \frac{400}{27} \times \frac{100}{200}$ mL

c) $300 \times \frac{300}{400} \times \frac{200}{100}$ mL

d) $300 \times \frac{400}{300} \times \frac{100}{200}$ mL

32. A metal which does NOT readily release H_2 (hydrogen) from cold water is

a) magnesium.

b) sodium.

c) potassium.

d) calcium.

33. The reaction between gaseous hydrogen chloride and water is best represented by

a) $HCl_{(g)} + H_2O \longrightarrow H_2^{2+}(aq) + Cl^-(aq)$

b) $HCl_{(g)} + H_2O \longrightarrow H_{2(g)} + HClO_{(aq)}$

c) $HCl_{(g)} + H_2O \longrightarrow H^+(aq) + ClO^-(aq)$

d) $HCl_{(g)} + H_2O \longrightarrow H_3O^+(aq) + Cl^-(aq)$

34. Which of the following elements has the LOWEST first ionization energy (i.e. the energy required to remove one electron)?

a) fluorine

b) neon

c) sodium

d) magnesium

35. If 2 containers of different ideal gases under the same conditions of temperature and pressure have the same number of molecules, the gas samples must also

a) be of the same substance

b) have the same numbers of atoms

c) have the same mass

d) have the same volume

36. How many protons, neutrons, and electrons are there in one potassium ion, $^{39}_{19}K^+$

a) 39 protons, 39 neutrons, 39 electrons

b) 19 protons, 20 neutrons, 18 electrons

c) 19 protons, 20 neutrons, 20 electrons

d) 20 protons, 19 neutrons, 19 electrons

37. At a constant pressure, 20L of a gas at 400 K are expanded to 30 L. The final temperature of the gas must be

a) 267 K

b) 390 K

c) 600 K

d) 4000 K

38. Which of the state(s) of matter fit(s) the following characteristics?

-diffusion occurs
-no fixed shape
-molecular motion takes place

a) solid

b) liquid

c) gas

d) liquid and gas

39. Which of the following compounds would be most highly dissociated in water at room temperature and pressure?

a) ammonia (NH_3)

b) acetic acid (CH_3COOH)

c) hydrochloric acid (HCl)

d) methyl alcohol (CH_3OH)

40. Some aqueous solutions are strongly basic because

a) they contain a high concentration of metallic ions.

b) they contain a high concentration of hydronium ions.

c) they hardly dissociate into their constituent ions.

d) they contain a high concentration of hydroxide ions.

41. How many atoms are represented by the formula $Mg(OH)_2$?

a) 5

b) 6

c) 3

d) 4

42. In the Periodic Table elements with similar properties are grouped in

a) horizontal rows.

b) vertical columns.

c) periods.

d) diagonal rows.

43. Given that the relative atomic masses of Pb, H, Fe, Ca and He are 207, 1.0, 56, 40 and 4.0 respectively, 20.7 g of lead has approximately the same number of atoms as

a) 1.0 g of hydrogen

b) 5.6 g of iron

c) 56 g of calcium

d) 4.0 g of helium

44. The Law of Definite Proportions states that elements always combine with each other

a) spontaneously.

b) with the evolution of heat.

c) in a definite ratio by mass.

d) in a definite ratio by volume.

45. When <u>gases combine</u> chemically or are produced in a chemical reaction, there is always a simple whole number ratio between their

a) masses.

b) densities.

c) volumes.

d) critical temperatures.

46. An Ontario sample of the compound sodium chloride (NaCl) is found to consist of 39.3% sodium, by mass and 60.7% chlorine, by mass. A sample of pure sodium chloride found in the southern United States consists of

a) 19.7% sodium and 80.3% chlorine.

b) 39.3% sodium and 60.7% chlorine.

c) 69.7% sodium and 30.3% chlorine.

d) 79.6% sodium and 20.4% chlorine.

47. 1.0 L of a 0.5 mol/L solution of sodium sulfide, Na_2S, contains

a) 0.5 L of water.

b) 1.0 mol of $Na^+_{(aq)}$ and 0.5 mol of $S^{2-}_{(aq)}$.

c) 1.0 mol of all solute particles.

d) 0.5 mol of $Na^+_{(aq)}$ and 0.5 mol of $S^{2-}_{(aq)}$.

48. The reaction between H_2 (hydrogen) and O_2 (oxygen) is:

$$2H_2 + O_2 \longrightarrow 2H_2O$$

The mass of O_2 required to completely convert 4.0 g of H_2 to water is

a) 8.0 g

b) 2.0 g

c) 16 g

d) 32 g

49. Hydrogen gas reacts with hot copper(II) oxide according to the equation:

$$H_{2(g)} + CuO_{(s)} \longrightarrow Cu_{(s)} + H_2O_{(g)}$$

The number of moles of water formed when 159 g of CuO are completely reduced to copper metal is

a) 1.00

b) 2.00

c) 1.50

d) 1.59

50. When metals are burned in oxygen, the products are most often

a) bases.

b) acids.

c) acidic oxides.

d) basic oxides.

51. Carbon disulphide (CS_2) burns in air; the reaction is described by the following equation:

$$CS_2 + 3O_2 \longrightarrow CO_2 + 2SO_2$$

How many <u>moles</u> of oxygen are required to produce 11 g of carbon dioxide (CO_2) ?

a) $\frac{1}{11}$ mol

b) $\frac{3}{4}$ mol

c) $\frac{4}{3}$ mol

d) 3 mol

52. Consider the equation:

$$CO_{(g)} + \frac{1}{2} O_{2(g)} \longrightarrow CO_{2(g)}$$

"20 mL of carbon monoxide, CO, and 10 mL of oxygen, O_2, react forming 20 mL of carbon dioxide, CO_2." This statement illustrates all of the following EXCEPT

a) Avogadro's Principle

b) Law of Multiple Proportions

c) Boyle's Law

d) Law of Combining Gas Volumes

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This is Booklet 3. Make sure you answer these questions on the answer sheet in the section which says Booklet 3.

61. Which one of the following equations is balanced?

a) $2KClO_3 \longrightarrow KCl + 3O_2$

b) $H_2O + Na \longrightarrow NaOH + H_2$

c) $Zn + H_2SO_4 \longrightarrow ZnSO_4 + 2H_2$

d) $2H_2O + Ca \longrightarrow Ca(OH)_2 + H_2$

62. The most highly ionic bonds exist between

a) sodium and fluorine

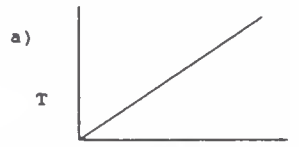
b) potassium and fluorine

c) lithium and fluorine

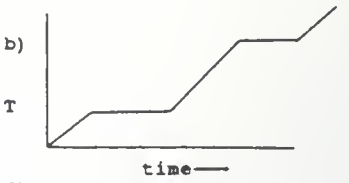
d) chlorine and fluorine

63. Which of the following diagrams best illustrates the temperature-time graph for the heating of ice at -10^oC to produce steam at 125^oC?

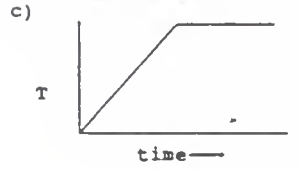
a)



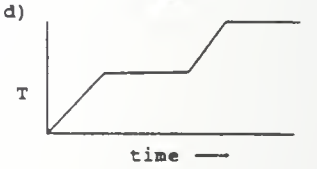
b)



c)



d)



64. During the electrolysis of water, hydrogen and oxygen gas are produced.

$$2H_2O_{(l)} \longrightarrow 2H_{2(g)} + O_{2(g)}$$

The number of <u>moles of electrons</u> required to decompose sufficient water to produce <u>four moles</u> of hydrogen gas (H_2) is

a) 2 moles.

b) 4 moles.

c) 8 moles.

d) 12 moles.

65. Phosphorus, P_4, burns in air to form the oxide, P_4O_{10}. The balanced equation for the reaction is

a) $P_4 + 10\ O \longrightarrow P_4O_{10}$.

b) $P_4 + 5\ O_2 \longrightarrow P_4O_{10}$.

c) $4P + 10\ O \longrightarrow P_4\ O_{10}$.

d) $P_4 + 5\ O_2 \longrightarrow 2P_4O_{10}$.

66. One mole of a pure substance contains approximately

a) 2.17×10^{-18} molecules.

b) 2.24×10^{5} molecules.

c) 2.3×10^{23} molecules.

d) 6.02×10^{23} molecules.

67. An atom becomes a negatively charged ion when it

a) loses neutrons.

b) gains electrons.

c) gains protons.

d) loses electrons.

68. An empty flask (one with all the air pumped out) is found to have a mass of 110.02 g. When filled with $H_{2(g)}$ (hydrogen gas), the flask is found to have a mass of 110.06 g. When filled with an unknown gas, it has a mass of 110.66 g. Which one of the following formulas could be that of the unknown gas?

a) O_2 (oxygen) -relative atomic mass = 16

b) He (helium) -relative atomic mass = 4

c) F_2 (fluorine) -relative atomic mass = 19

d) H_2O (water) -relative atomic mass = 18

69. Consider the species

Al^{3+}, Si, F^-, Ne

The species that has a different number of electrons is

a) Al^{3+}

b) Si

c) F^-

d) Ne

70. A solution which contains an equal number of hydrogen ions and hydroxide ions is

a) an acidic solution.

b) a basic solution.

c) a neutral solution.

d) a solid solution.

71. In the neutralization reaction between strontium hydroxide, $Sr(OH)_2$, and perchloric acid, $HClO_4$, the products are water and

a) $Sr(ClO_4)_{2(aq)}$

b) $Sr_2Cl_{2(aq)}$

c) $Sr_2ClO_{4(aq)}$

d) $SrClO_{3(aq)}$

72. 100 mL of an ideal gas initially at 27°C is heated to 270°C at constant pressure. The new volume will be

a) 55 mL

b) 181 mL

c) 550 mL

d) 1000 mL

73. The concentration of a solution containing 4 g of NaOH (sodium hydroxide) in 100 mL of solution is

a) 1 mol/L

b) 2 mol/L

c) 3 mol/L

d) 4 mol/L

74. If the pressure is kept constant the volume of a given mass of gas varies

a) inversely with the Celsius temperature.

b) directly with the absolute or Kelvin temperature.

c) inversely with the absolute or Kelvin temperature.

d) directly with all temperature units.

75. A quantity of gas collected at 298 K and 101 kPa occupies a volume of 200 mL. If the pressure on the gas is doubled and its temperature is raised to 596 K, the volume occupied by the gas will be

a) 50.0 mL

b) 100 mL

c) 200 mL

d) 800 mL

76. Three moles of sodium hydroxide, NaOH, are added to one mole of phosphoric acid, H_3PO_4. The resulting salt is sodium

a) phosphate.

b) monohydrogen phosphate.

c) dihydrogen phosphate.

d) trihydrogen phosphate.

77. The unbalanced equation representing the neutralization of $Al(OH)_3$ (aluminum hydroxide) with HCl (hydrochloric acid) is:

$$Al(OH)_3 + HCl \longrightarrow AlCl_3 + H_2O$$

When the equation is balanced with the smallest whole-numbers, the coefficient of HCl is

a) 1

b) 2

c) 3

d) 4

78. Breaking a compound down into its elements is known as

a) decomposition.

b) fission.

c) synthesis.

d) transmutation.

79. The mass numbers of two naturally occurring isotopes of chlorine are 35 and 37. Which of the following statements is true?

a) Chlorine isotopes have different nuclear charges.

b) Cl-35 and Cl-37 have different chemical properties.

c) Some naturally occurring chlorine nuclei contain 20 protons.

d) Some naturally occurring chlorine nuclei contain 20 neutrons.

80. A hydrocarbon gas has a relative molecular mass of approximately 44. The compound is 81.8% carbon and 18.2% hydrogen by mass. The molecular formula of the gas is

a) C_2H_6

b) C_3H_8

c) C_4H_{10}

d) C_5H_{12}

81. An example of an element is

a) carbon dioxide.

b) air.

c) brass.

d) sulphur.

82. Values of 1st, 2nd and 3rd ionization energies (i.e. the energy required to remove that electron) of an unknown element are found to be as follows:

E_1 = 9.32 kJ/mol E_2 = 258 kJ/mol E_3 = 268 kJ/mol

In which group of the Periodic Table do you expect to find this element?

a) I

b) II

c) VI

d) IV

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91. Methanol (CH_3OH) burns according to the equation:

$$2CH_3OH_{(l)} + 3O_{2(g)} \longrightarrow 2CO_{2(g)} + 4H_2O_{(g)} + \text{heat}$$

What volume of carbon dioxide (measured at 298 K and 101 kPa pressure) could be produced from 0.250 moles of methanol?

a) 6.11 L

b) 22.4 L

c) 44.8 L

d) 48.9 L

92. Nitrogen gas (N_2) and hydrogen gas (H_2) react to produce ammonia (NH_3) according to the following balanced equation:

$$N_{2(g)} + 3H_{2(g)} \longrightarrow 2NH_{3(g)}$$

How many litres of hydrogen gas (H_2) measured at 100 kPa and 273 K are required to react with 11.2 L of nitrogen gas, N_2, measured at 100 kPa and 273 K?

a) 16.8 L

b) 22.4 L

c) 33.6 L

d) 67.2 L

93. A sample of O_2 (oxygen), at STP has a mass of 32 g. The mass of the same number of molecules of H_2 (hydrogen) is

a) 1.0 g

b) 2.0 g

c) 16 g

d) 4.0 g

94. What volume of dry oxygen, at STP can be obtained by heating 245 g of potassium chlorate ($KClO_3$)?

$$2KClO_3 \longrightarrow 2KCl + 3O_2$$

a) 22.4 L

b) 67.2 L

c) 245 L

d) 490 L

95. When potassium hydroxide reacts with sulphuric acid the products are

a) a salt and hydrogen.

b) sulphur dioxide and water.

c) a metallic oxide and water.

d) a salt and water.

96. Which of the following electron configurations represents the most reactive non-metal?

a) 2, 8, 1

b) 2, 8, 3

c) 2, 8, 7

d) 2, 8, 8

97. A pure substance that contains more than one type of atom is called

a) a solution.

b) a compound.

c) an element.

d) an allotrope.

98. The greater the electronegativity of an element the greater the tendency of the element to

a) gain electrons.

b) lose electrons.

c) gain protons.

d) lose protons.

99. If XBr_2 is the formula for a metallic bromide, the formula for the oxide of metal X is

a) X_2O

b) XO

c) X_2O_3

d) XO_2

100. The molar mass of $Al_2(CO_3)_3$ is

a) 114 g

b) 207 g

c) 210 g

d) 234 g

101. The reaction of aqueous solutions of sodium chloride, NaCl, and silver nitrate, $AgNO_3$, is represented by the equation:

$$Na^+ + Cl^- + Ag^+ + NO_3^- \longrightarrow AgCl_{(s)} + Na^+ + NO_3^-$$

The reaction proceeds nearly to completion because

a) the sodium and nitrate ions do not react.

b) the reactants are water soluble.

c) an insoluble product is formed.

d) the reaction is reversible.

102. When the pressure on 1.0 L of gas is doubled and the temperature on the Kelvin scale is tripled, the volume becomes

a) $\frac{2}{3}$ L

b) $\frac{3}{2}$ L

c) 6 L

d) $\frac{1}{6}$ L

103. One example of an oxide that reacts with water to form a basic solution is

a) SO_2 (sulfur dioxide)

b) CO_2 (carbon dioxide)

c) P_4O_{10} (phosphorus(V) oxide)

d) CaO (calcium oxide)

104. The correct formula for manganese(IV) oxide is

a) Mn_4O

b) MnO_4

c) Mn_2O

d) MnO_2

105. Boyle's Law can be expressed by the relation

a) $V_1T_2 = V_2T_1$

b) $V_1T_1 = V_2T_2$

c) $P_1V_1 = P_2V_2$

d) $P_1V_2 = P_2V_1$

106. The group of particles having the same number of electrons in each particle is

a) He Li^+ Be

b) Ne Na^+ Mg^{2+}

c) Ar Cl^- S

d) Ar K^+ O^{2-}

107. When the pressure exerted on 1 L of an ideal gas is tripled, and the absolute temperature is doubled, the volume becomes

a) $\frac{1}{6}$ L

b) $\frac{2}{3}$ L

c) $\frac{3}{2}$ L

d) 6 L

108. Which of the following elements will displace hydrogen most readily from a hydrochloric acid solution?

a) mercury

b) silver

c) aluminum

d) copper

109. A physical change in a substance

a) changes only the state of the substance.

b) changes it into a different substance.

c) could be a synthesis reaction.

d) causes a change in mass of the substance.

110. What volume of 5.0 mol/L HCl (hydrochloric acid) is needed to prepare 400 mL of 0.25 mol/L HCl solution?

a) 20 mL

b) 2.0 mL

c) 40 mL

d) 4.0 mL

111. One gram of sodium chloride, NaCl, is dissolved in enough water to make 415 mL of solution. The concentration of NaCl in the solution is

a) 4×10^{-5} mol/L

b) 7×10^{-3} mol/L

c) 4×10^{-2} mol/L

d) 2 mol/L

112. A volume of 25.0 L of an ideal gas is at 202 kPa pressure and 300 K. At standard temperature and pressure, the volume of the gas would be

a) $\frac{25.0 \times 101 \times 300}{202 \times 273}$ L

b) $\frac{25.0 \times 202 \times 273}{101 \times 300}$ L

c) $\frac{25.0 \times 101 \times 273}{202 \times 300}$ L

d) $\frac{25.0 \times 202 \times 300}{101 \times 273}$ L

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121. An unknown material is added to water and stirred. On filtration a residue remains on the filter paper; further experiments show that the quantity of residue is unaffected by the addition of more water. When the filtrate is evaporated, a solid residue is found in the container.

From this information, it can be concluded that the original material was a(n)

a) mixture

b) element

c) pure substance

d) compound

122. You have examined a material and all **BUT** one of the following indicate that it is a pure substance. Which is the factor that shows it must be a mixture?

a) it is a uniform white powder

b) it is completely soluble in water

c) it looks like salt

d) it melts between 245 and 300°C

123. If Z represents the atomic number of an element and A represents its mass number, then the number of neutrons in one atom of the element is

a) A

b) A + Z

c) A - Z

d) Z - A

124. Consider the electron configurations for the elements V, W, X and Y

Element	Electron Configuration
V	2, 8, 6
W	2, 8, 7
X	2, 8, 8
Y	2, 8, 8, 1

The most electronegative (i.e. gains electrons most easily) element is

a) V

b) W

c) X

d) Y

125. Sharing of electrons in forming a bond always involves

a) formation of positive and negative ions.

b) shared electrons located equidistant from both nuclei.

c) lower energy content for bonded than unbonded atoms.

d) shared electrons being attracted more by one atom.

126. The nuclear atom was first proposed by

a) Rutherford.

b) Bohr.

c) Chadwick.

d) Dalton.

127. The Roman numeral which would be included in the correct name for the compound Fe_2O_3 is

a) V

b) II

c) III

d) IV

128. Within a vertical group of elements in the Periodic Table, such as Group I, Li, Na, K, Rb, Cs, the first ionization energy (i.e. the energy required to remove one electron)

a) increases with increasing atomic radius.

b) decreases with increasing atomic radius.

c) stays the same.

d) behaves unpredictably.

129. The number of moles of He (helium) in 100 g of helium is

a) 12.5

b) 25.0

c) 50.0

d) 100

130. What mass of $CaCO_3$ (calcium carbonate) is required to produce 84 g of CaO (calcium oxide)?

$$CaCO_3 \longrightarrow CaO + CO_2$$

a) 66.6 g

b) 84.0 g

c) 100 g

d) 150 g

131. The volume of uncombined gas remaining after exploding a mixture of 4 mL of hydrogen gas and 16 mL of oxygen gas is (all volumes recorded at STP):

a) 9 mL

b) 8 mL

c) 12 mL

d) 14 mL

132. In the reaction described by the equation:

$$2KClO_3 \longrightarrow 2KCl + 3O_2$$

The number of moles of $KClO_3$ (potassium chlorate) required to produce 1.0 mole of O_2 (oxygen) is

a) 0.67

b) 2.0

c) 3.0

d) 1.5

133. Hydrogen and oxygen gases combine to form water vapour according to this equation:

$$2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(g)} + \text{Energy}$$

Provided the pressure and temperature are such that water is gaseous, the volume ratio of hydrogen consumed to water vapour produced is

a) 1:1

b) 8:1

c) 2:1

d) 1:2

134. To change a temperature reading from the Kelvin scale to the Celsius scale

a) add 273.

b) multiply by $\frac{273}{100}$.

c) multiply by $\frac{100}{273}$.

d) Subtract 273.

135. The expression "absolute zero" refers to:

a) the temperature at which water freezes.

b) -273 K.

c) $0^{\circ}C$.

d) 0 K.

136. The formula of a metallic fluoride is XF_2; the formula of the corresponding metallic phosphate is

a) XPO_4

b) X_2PO_4

c) $X_2(PO_4)_3$

d) $X_3(PO_4)_2$

137. If alcohol is burned in air and the products of combustion are passed through limewater, a white precipitate is produced. This result provides evidence that one of the constituent elements of the alcohol is

a) carbon.

b) chlorine.

c) hydrogen.

d) oxygen.

138. The boiling point of oxygen is $-183^{\circ}C$, and its freezing point is $-219^{\circ}C$. Within 50 K of absolute zero, oxygen is a

a) gas.

b) solution.

c) liquid.

d) solid.

139. Which of the following substances is least soluble in water at $25^{\circ}C$?

a) sodium chloride

b) silver chloride

c) sodium hydroxide

d) ammonium nitrate

140. $N_{2(g)} + 3H_{2(g)} \longrightarrow 2NH_{3(g)}$

What volume of nitrogen reacts with 1.12 L of hydrogen to form ammonia (all gases are measured at STP)?

a) 0.373 L

b) 1.12 L

c) 3.36 L

d) 22.4 L

141. The number of moles of KOH (potassium hydroxide) needed to prepare 2 L of a 2 mol/L solution of KOH is

a) 1

b) 2

c) 3

d) 4

142. What is the volume of 16 g of O_2 (oxygen) gas at STP?

a) 2.24 L

b) 11.2 L

c) 22.4 L

d) 44.8 L

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INSTRUCTIONS:

On the special **YELLOW** answer sheet, indicate your name, the name of your school, school board, and teacher. Then provide a complete answer on the answer sheet in the places corresponding to the sections of the question.

The problem which follows has many different solutions. The solution which you provide may or may not require all of the equipment and supplies suggested. You may also provide a solution which requires materials not on the list.

Outline your solution in as much detail as possible. Number each of the steps and remember to describe any calculations necessary to solve the problem.

QUESTION:

The chemist is frequently called upon to identify the contents of a series of unlabelled bottles. The chemist is NEVER allowed to taste any of the materials in the laboratory.

The labels have fallen off five bottles of white solids. The labels, in alphabetical order are, barium hydroxide, calcium carbonate, citric acid, sodium chloride and sucrose.

Design an experiment or a series of experiments to identify the contents of each of the bottles so that the appropriate labels may be returned to the correct bottles.

Some of the material that you might find useful in solving this problem is listed below:

Balance
Barometer
Beakers
Bunsen burner
Buret
Buret clamps

Clamps (ring)
Clamps (screw type)
Conductivity apparatus
Cover glasses
Crucibles & covers

Delivery tubes
Distilled water

Erlenmeyer flasks
Evaporating dishes
Eye droppers

Filter paper
Funnels

Gas collecting bottles
Gas measuring tubes
Gauze mats
Glass cutting files
Glass plates
Glass tubing
Graduated cylinders

Hydrochloric acid solution
Litmus paper Blue
Litmus paper Red

Matches

pH meter
pH paper
Pipet

Rubber stoppers

Silver nitrate solution
Stop watch
Stirring rods
Support stands

Test tubes
Thermometers
Tongs
Tweezers

Wax pencil
Wood splint

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CHEMISTRY AND PHYSICS

Ministry of Education Ontario — Program Implementation and Review Branch

INSTRUCTIONS:

On the special BLUE answer sheet, indicate your name, the name of your school, school board, and teacher. Then provide a complete answer on the answer sheet in the places corresponding to the sections of the question.

QUESTION:

Most members of the public will readily recognize Acid Rain as one of the impacts that chemistry has had on our environment. The action of acid precipitation on lakes, rivers, and forests is seen as a real threat.

a) On your answer sheet, name one substance that causes Acid Rain when released in the air.

b) Write a balanced chemical equation that describes the formation of this substance.

c) Identify one significant source of these emissions.

d) Control of Acid Rain involves at least three factors:

   i) technology
   ii) economics
   iii) politics (local, provincial, federal and international)

In a paragraph of 50-100 words, outline and explain briefly some of the problems in one of these three areas that form obstacles to the effective control of Acid Rain.

Chemistry

Advanced Level
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INSTRUCTIONS:

On the special GREEN answer sheet, indicate your name, the name of your school, school board, and teacher. Then provide a complete answer on the answer sheet in the places corresponding to the sections of the question.

The problem which follows has many different solutions. The solution which you provide may or may not require all of the equipment and supplies suggested. You may also provide a solution which requires materials not on the list.

Outline your solution in as much detail as possible. Number each of the steps and remember to describe any calculations necessary to solve the problem.

QUESTION:

Many commercial medicine tablets react with water and release gas. The identity of the gas can be determined both qualitatively and quantitatively. The chemist is NEVER allowed to taste any of the materials in the laboratory.

Design an experiment or a series of experiments to determine the mass and the molar mass of the gas that is produced when a commercial tablet is added to water.

Some of the material that you might find useful in solving this problem is listed below:

Balance
Barometer
Beakers
Bromothymol blue solution
Bunsen burner
Buret
Buret clamps

Calcium hydroxide solution
Clamps (ring)
Clamps (screw type)
Conductivity apparatus
Copper wire
Cover glasses
Crucibles & covers

Delivery tubes
Distilled water

Erlenmeyer flasks
Evaporating dishes
Eye droppers

Filter paper
Funnels

Gas collecting bottles
Gas measuring tubes
Gauze mats
Glass cutting files
Glass plates
Glass tubing
Graduated cylinders

Hydrochloric acid, 0.1 mol/L

Litmus paper Blue
Litmus paper Red

Matches

pH meter
pH paper
Pinch clamps
Pipets
Plastic bags

Rubber stoppers
Rubber tubing

Silver nitrate solution
Sodium hydroxide, 0.1 mol/L
Serum caps
Stop watch
Stirring rods
Support stands
Support tanks
Syringe needle
Syringe, 50 mL

Test tubes
Thermometers
Tongs
Tweezers

Wax pencil
Wood splints

Chemistry

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CHEMISTRY AND PHYSICS

Ministry of Education Ontario
Program Implementation and Review Branch

INSTRUCTIONS:

On the special GOLD answer sheet, indicate your name, the name of your school, school board, and teacher. Then provide a complete answer on the answer sheet in the places corresponding to the sections of the question.

The problem which follows has many different solutions. The solution which you provide may or may not require all of the equipment and supplies suggested. You may also provide a solution which requires materials not on the list.

Outline your solution in as much detail as possible. Number each of the steps and remember to describe any calculations necessary to solve the problem.

QUESTION:

Alloys are solid solutions of two or more metals. Alloys are usually produced by mixing the metals when they are liquid (molten) and then allowing them to cool to room temperature. The concentration of the metals in the alloy is chosen in order to give specific properties to the alloy. Sodium/lead alloys are used in industry as drying agents.

Design an experiment or a series of experiments to determine the concentration (% by mass) of sodium in a given sample of a sodium/lead alloy.

Some of the material that you might find useful in solving this problem is listed below:

Balance
Barometer
Beakers
Bromothymol blue solution
Bunsen burner
Buret
Buret clamps

Calcium hydroxide solution
Clamps (ring)
Clamps (screw type)
Conductivity apparatus
Copper wire
Cover glasses
Crucibles & covers

Delivery tubes
Distilled water

Erlenmeyer flasks
Evaporating dishes
Eye droppers

Filter paper
Funnels

Gas collecting bottles
Gas measuring tubes
Gauze mats
Glass cutting files
Glass plates
Glass tubing
Graduated cylinders

Hydrochloric acid, 0.1 mol/L

Litmus paper Blue
Litmus paper Red

Matches

Oven
Overflow can

Pinch clamps
Pipets
Plastic bags

Rubber stoppers
Rubber tubing

Sodium hydroxide, 0.1 mol/L
Serum caps
Stop watch
Stirring rods
Support stands
Support tanks
Syringe needle
Syringe, 50 mL

Test tubes
Thermometers
Tongs
Tweezers

Wax pencil
Wood splints

Chemistry

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PROVINCIAL REVIEWS

CHEMISTRY AND PHYSICS

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INSTRUCTIONS:

On the special PINK answer sheet, indicate your name, the name of your school, school board, and teacher. Then provide a complete answer on the answer sheet in the places corresponding to the sections of the question.

QUESTION:

Attached to this page is a piece of material.

a) Describe the properties of this material and indicate how these properties could help you to determine whether it is a:

   i) pure substance or mixture

   ii) metal or non-metal

b) If laboratory facilities were available, what other tests could you do to make these determinations? Indicate in your answer, what observations could be expected for each classification.

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